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THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XI.—*History of the Changes in the Mt. Loa Craters;* by JAMES D. DANA. Part II, on MOKUAWEOWEO, or the SUMMIT CRATER, continued.

[Continued from page 32.]

GENERAL SUMMARY WITH CONCLUSIONS.

THE subjects connected with Mount Loa and the summit crater considered in the following summary and conclusions are the following:

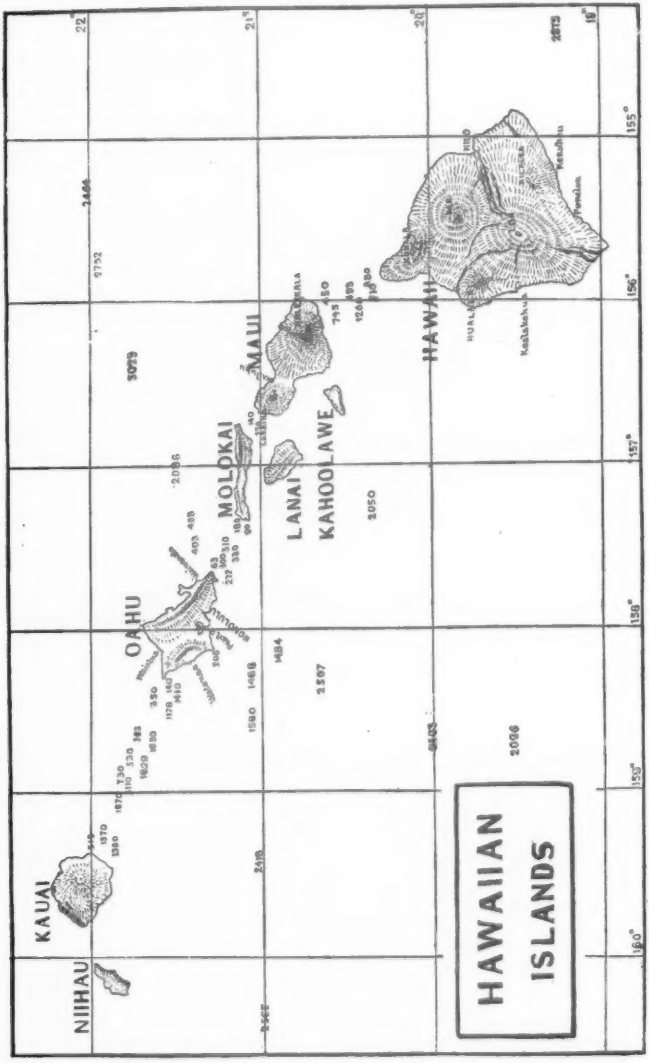
1. *The times and time-intervals of eruptions and of summit illuminations or activity*, with reference to (1) periodicity, (2) relations to seasons, (3) variations in activity since 1843, and (4), the changes in the depth of the crater.

2. *The ordinary activity within the summit crater.*

3. *Causes of the ordinary movements within the crater.*

Next follows Part III, treating of the causes of eruptions in Mt. Loa and Kilauea, and afterward, of the relations of the two volcanoes.

For the further illustration of the volcanoes the following map of the Hawaiian Islands is here introduced. Besides showing the forms of the islands, their relative positions and the two parallel lines between Oahu and Hawaii, it gives also the depths from the soundings of the Challenger and of vessels of the U. S. Navy, and others made with reference to telegraph-lines between the islands for which the map is indebted to the Hawaiian Government Survey.


NIIHAU
KAUAI
OAHU
MOLOKAI
MAUI
LANAI
KAHOOLAWE
HAWAII
HAWAIIAN ISLANDS
160°
159°
158°
157°
156°
155°
22°
21°
20°
19°

1. *Times and Time-intervals of Eruptions.*

1. *Question of Periodicity.*—Commencing with the eruption of 1832, there have been nine registered eruptions of Mt. Loa. Their times and heights of outflow, directions and lengths of stream, and relations to earthquakes, are stated in the following table:

	Reported Earthquakes.	Height of chief out-flow.	Direction and length of flow.
1. 1832: June 20, 2-3 weeks.	none.	Summit.	No outflow.
2. 1843: Jan. 9 to end Feb., 1½ mos.	none.	11,000.	N.N.W., 15 m.
3. 1851: Aug. 8, for 3 or 4 days,	none.	12,900.	W., 10 m.
4. 1852: Feb. 17 into March, 20 d'ys	none.	little over 10,000	E., 20 m.
5. 1855: Aug. 11 to Nov., '56, 15 ms	none.	12,000.	E., 26 m.
6. 1859: Jan. 23 to Nov. 25, 10 mos.	none.	10,500.	N.W., 33 m.
7. 1868: March 27, 16 days,	earthquakes	3,000.	S., 10–11 m.
8. 1880: Nov. 5 to Aug., '81, 9 mos.	none.	11,100.	E., 30 m.
9. 1887: Jan. 18, 10 days,	earthquakes	5,600.	S. 14 m.

The intervals between these eruptions, reckoning (A) between their beginnings, and (B) between the end of each and the beginning of the following one, are:

	A.	B.
Between eruptions—1 and 2	10 years 8 mos.	10 years 7 mos.
2 and 3	8 " 7 "	8 " 5½ "
3 and 4	6⅓ "	6 "
4 and 5	3 " 6 "	3 " 5 "
5 and 6	3 " 5 "	2 " 2 "
6 and 7	9 " 2 "	8 " 4 "
7 and 8	12 " 7 "	12 " 7 "
8 and 9	6 " 2½ "	5 " 6 "

The eruptions above enumerated, that of 1832 perhaps excepted, were great eruptions; that is they had outside or subaerial outflows. But the history shows that at other times in the sixty-five years the summit of the mountain has been often brilliantly lighted, and surmounted with a column of clouds of great height, made apparently from the escaping vapors, which became a lofty column of light at night. These summit illuminations have been shown to be evidence (p. 27) not merely of action in or about the crater, but decisively of a boiling or fountain-like activity in the liquid lavas, if not also of out-flowing streams. The drifting of Pélé's hair on such occasions 35 miles to Hilo is as good testimony to the playing of jets or fountains as a note from an observer at the summit.

Moreover, we have learned from Kilauea that these times of brilliant action within the crater may be followed by subterranean or submarine discharges when not by subaerial; and therefore that they are not always merely the flaring up and

fading out of the crater-fires. They announce that *the top of the Mt. Loa column of liquid lavas is in the crater*, or has its maximum length, and is at serious work, even if no outbreak ensues.

The following table contains the times of these minor displays, as well as those of the admitted greater eruptions. In the table the latter are indicated by italics:

	Dates.	Conditions at the Summit.
1.	1832. June 20.	Bright light at the summit, 2–3 weeks.
2.	1843. *Jan.* 9 *to late in Feb.;* 1½ *mos.*	Clouds; Jan. 10–17, bright light.
3.	1849. May, 2 to 3 weeks.	Brilliant light; just after activity in K.
4.	1851. *Aug.* 8; 3 *or* 4 *dags.*	Bright light for 3 or 4 days.
5.	1852. *Feb.* 15 *to June; about* 4 *mos.*	Brilliant light for 24 hours.
6.	1855. *Aug.* 11 *to Nov.*, 1856; 15 *mos.*	Bright light at beginning.
7.	1859. *Jan.* 23 *to Nov.* 25; 10 *mos.*	Brilliant light at first.
8.	1865. Dec. 30; 4 mos.	Brilliant light for 4 mos., varying; at close, Kilauea increases its activity.
9.	1868. *Mar.* 27 *to Apr.* 12; *the flow* 4 *days.*	Bright light from March 27 to 30.
10.	1872. Aug. 10, into September.	Brilliant; a lava fountain of 500 feet; a tidal wave on the coast; K. very active.
11.	1873. Jan. 6, 7; 2 days.	Brilliant.
12.	1873. Apr. 20 to Oct., 1874; 18 mos.	Brilliant more or less for 18 mos.; in June and Aug., '73, a lava fountain. 300-600 feet.
13.	1875. Aug. 11; one week.	Brilliant.
14.	1876. Feb. 13; few days.	Brilliant.
15.	1877. Feb. 14; few days.	Brilliant; a submarine eruption.
16.	1880. May 1.	Brilliant; a lava fountain of 900 feet; Pélé's hair fell in Hilo.
17.	1880. *Nov.* 5 *to Aug.*, 1881; 9 *mos.*	Bright for a few days.
18.	1887. *Jan.* 16; *ten days.*	Bright for a few hours.
19.	1887. Nov. 25, into Feb.; 1 mth.	Vapors; no light seen.

The table contains the dates of ten periods of summit activity or illumination independent of the great eruptions; some short, but others prolonged for months, and varying greatly from time to time in brightness.

All these minor displays have taken place without initiating or announcing earthquakes.

It is obvious from the tables that the lengths of the intervals between the eruptions and the summit illuminations are too various, as far as now understood, to sustain the idea of periodicity.

2. *Relation to seasons.*—The evidence of a seasonal relation appears to be beyond question. Out of the whole number, 19, 5, counting in that of 1865, occurred in January, 3 in February, 4 in March, April and May, and 1 in June, making 13 in the first six months of the year. Of the remainder, 4 commenced in August and 2 in November. Thus 15 out of the 19 took place in the wetter season. Add to these facts those from Kilauea mentioned in volume xxxv, p. 16, where the months given are March ?, January or June, May, May, Octo-

ber, April, April, March, and the number for the same months of the year becomes 20 or 21 out of 27.*

Full meteorological tables for a comparison of the months as to precipitation, both at the base and summit of the mountain, do not exist, and the discussion of this important question has, therefore, to be left unfinished.

I have received the following notes on the snows of Mt. Loa in a recent letter from Mr. J. S. Emerson of the Hawaiian Government Survey. "The snow-cap of Mt. Loa in general may be considered as making its first appearance in the early part of November, and as lasting until late into March. This is my impression from observations the past season, which I think has not been particularly exceptional. During the early part of November the snow-fall was quite light, and seemed to melt rapidly away at its lower edges. By the 25th there had been two heavy snow-storms covering the mountain top with a thick coat, which lasted all through the winter. The snows are usually the heaviest in the month of February, I think, though I did not see the mountain during that month this year. My last view of Mt. Loa was on March 29th, when I could just distinguish patches or streaks of snow on the more protected portions of the summit."

The *relation to barometric changes* is an important subject for future study, with respect to which we have now no knowledge. There are also variations in the amount of vapors over the active craters dependent on *hygrometric changes* to be investigated.

In view of the above facts it is probable that if there is any periodicity in eruptions, it is more or less dependent on meteorological cycles.

3. *Variations in activity since* 1843.—The copiousness of the subaerial discharges has diminished greatly since 1859. Before the end of that year, or in the 17 years from 1843 to 1860, five of the eight great eruptions had occurred; and of the three in the following 27 years, only one, that of 1880–81, was of great length.

The frequent occurrence of the brilliant summit displays during the twelve years preceding the middle of 1880 is another striking fact. Six cases are reported, and one was prolonged with small interruptions for eighteen months.

The first of these displays occurred nearly $4\frac{1}{2}$ years after the eruption of 1868. But Mr. Coan, the mountain chronicler, was absent in this country during one year in the interval—from the spring of 1870 to that of 1871. After the summit-display of August, 1872, they came at short intervals, their

* This relation to the seasons, first recognized by Mr. Coan, is mentioned also by Mr. Green in his Vestiges etc., p. 332.

lengths from the end of one year to the beginning of another, reckoned in months, being 5, 3, 10, 6, 12. After February of 1877, there was the longer interval of $3\frac{1}{3}$ years. Such short-period alternations seem to imply the recurrence after each of a subterranean discharge somewhere, if not a subaerial. The display of 1877 quite certainly ended in a submarine eruption, and probably that of 1872, (pp. 29, 26).

4. *The changes in depth of the summit-crater.*—The changes since the year 1834, when the crater was visited by Douglas, have diminished its depth by at least 400 feet, if we may trust—as we probably ought to do—his measurement "with a line and plummet," making it 1,270 feet. In 1840, Lieut. Eld, U. S. N., of the Wilkes Exploring Expedition, made the depth on the west side 784 feet (p. 16), and in 1885, J. M. Alexander, 800 feet, (plate II).

We know nothing as to variations in the level of the floor after and before an eruption, and nothing as to the down-plunges which have followed discharges. The terrace-levels situated at the north and south ends of the crater may mark high lava-levels just previous to some ancient eruption; but they antedate history; for Wilkes's map (p. 17) shows that they existed in 1840 very much as now. The map, Plate 2, by J. M. Alexander, which contains his "estimates" of the depths of the terraces or "plateaus" below the highest point or summit, makes the terrace at the south end on a level with the upper of the two at the north end, suggesting thus that the two may mark one of the high-lava levels of the crater. In addition, it places the bottom of the South Crater (D), and that of the pit in the upper north terrace or plateau (A′), at or below the level of the bottom of the central crater, favoring the view that all three parts of Mokuaweoweo are still in active connection; which view is sustained by the facts (1) that the fountain of May, 1880, was a South Crater fountain, and (2) that the pit A′ was formed since 1874, as it is not in Lydgate's map of the crater of that year.

2. *The Ordinary activity of the Mt. Loa crater.*

1. *General course of action.*—Although but few ascents to the summit-crater have been made since the first by Douglas in 1834, and only four of these found the crater in action, there are still facts enough for important conclusions. The *cycle of changes* has been, beyond doubt, the same essentially as in Kilauea; that is, when a discharge takes place: (1) the lava of the lava-column within the central conduit of the mountain falls to a level some distance below the crater (say one or more hundred feet), as a consequence of the loss by the out-

flow. Then begins (2) a rising of the lava of the column until it again shows part of its fiery top in the bottom of the crater engaged in its usual projectile work, and until finally it has reached a maximum height; and then follows (3) a new discharge, and another time of inactivity for the crater.

2. *The projectile action within the crater.*—Projectile action in the Mt. Loa crater is in strong contrast with that of Kilauea. Instead of the Kilauea feature of low jets suggesting ordinary ebullition, with only occasional throws to a height of 100 to 200 feet, the descriptions of the summit action tell solely of fountains of clustered jets 75 to 600 feet, and even 900 feet high, as if the height of the jets or the intensity of the action was proportional to the height of the lava-column. The four accounts of this activity, one in 1872, two in 1873, and one in 1880, are alike in this respect. One of the two in 1873 describes the crater when the summit-light appeared feeble from below, and the other when brilliant, and the former is scarcely less marvellous in its fountains. The evidence is almost conclusive that such fountains are of ordinary occurrence. This was the opinion of Mr. Coan; and Mr. W. L. Green, in view of his summit observations in 1873 (p. 28) and the reported facts of others, ascribes to all the periods of summit illumination "great fountains."

3. *Causes of the Ordinary movements within the Crater.*

1. *The rise of the lava in the conduit.*—The rise of the conduit lava may be safely attributed in part, probably a large part, as in Kilauea, to the quietly-acting ascensive force in the lava-column.

The other volcanic agency of greatest prominence, as admitted for other volcanoes, is that of the *rising*, *expanding* and *escaping* vapors. The vesiculating effects of the vapors as regards the Mt. Loa flow of 1880–81 have been already described (xxxv, 222): and it remains to consider—

2. *The cause of the high projectile action in the summit crater.*—Higher projectile action in Mt. Loa than in Kilauea through the escape of elastic vapors might come (1) from greater viscidity in the lava; or (2) from less specific gravity of the material; or (3) from a larger supply of vapors. The first of these causes cannot be the right one, for greater viscidity should lead to high cinder ejections; on the contrary, the lavas show that they are as mobile as the Kilauea lavas by the velocity of the lava streams and all the attending phenomena, and more by the free play of the fountains. The second is set aside by the near identity of the lavas in density:

that of the Mt. Loa flow of 1880–81 being 2·98; that of ordinary Kilauea lava, 2·97–3·05; an old lava, from Waldron's ledge, excessively chrysolitic, 3·15.

If neither of these explanations meets the case, we have only the third to appeal to—a greater volume of elastic vapors. It is, accordingly, probable that the cause which can produce *occasional* jets of 100 to 200 feet in Kilauea is capable of producing the *prevailing* high jets or fountains of the summit of Mt. Loa.

But why should the volume of vapors in the lava-column be greatest at the summit? The amount of work done there is ordinarily at least 100 to 1000 times greater than in Kilauea: for the jets are 5 to 10 times higher.

This difference in amount could not be a fact if the vapors within the slowly ascending lavas were from the profound depths that supply the lava, or even from depths much below the sea-level. For, under such circumstances, (1) the difference in the amounts carried up to the two craters would be small, since the rate of supply from below would be essentially uniform; and (2) the difference in the height of the columns would be more favorable to Kilauea, whose lava-column rises above tide level but 3700 feet, than to Mt. Loa 9000 feet higher. The area of the floor of Kilauea exceeds that of Mt. Loa.

But if freshwater from precipitation over the island supplies the vapors, then the difference in the heights of the conduit lava-columns is greatly in Mt. Loa's favor. A section of its lava column at the sea-level may receive moisture during the whole time of its rise to the summit, a distance 3·8 times that for Kilauea. The ratio 3·8 to 1 for the difference in supply of moisture to the columns would be too large on account of the less precipitation over the upper part of the mountain and the much less extent of surface in this part; but it may safely be put at 2 to 1, if not 2½ to 1. The ascensive movement in the Mt. Loa lava-column may be somewhat more rapid than in the shorter conduit of Kilauea, provided the hotter central portion derives any upward thrust from the pressure of the cooler lateral portion, (xxxiv, . . .); and this cause would diminish the difference between the two as to the supply of vapor received; yet not largely.

The fact here apparently established—that only through waters from the island-precipitation could Mt. Loa get its larger supply—affords new evidence that *the inland waters are the chief source of the vapors concerned in Hawaiian volcanic action.*

Is there any other source of the Projectile action? The lava-fountains of the summit-crater are so marvelous in size considering the density of the lavas, so near the incredible, that we naturally seek for other possible explanations.

Hydrostatic pressure is out of consideration, inasmuch as the fountains are at the summit of the dome and at times throw their jets 50 to 100 feet above the mountain's top—over 14,000 feet above the sea-level.

Another source of projectile action has been suggested by Mr. Green, as briefly mentioned on a preceding page (xxxv, 216). In opposition to other writers on volcanoes, he sets aside the idea that vapor of water is concerned effectually in the projectile action even of Kilauea. The feeble amount of vapors observed by him over the fountain of the summit-crater in 1873, and the general absence of vapors from the flowing lava-streams of 1859 and 1880–81, besides other similar facts, have led him to his position on this point. He recognizes the fact* that great heaps and columns of clouds form over an active crater, and rise at times to a height of many thousands of feet; but accounts for these on the assumption that the heated current ascending from the active crater derives rapid accessions of air from either side, and this air, by being carried up to cold heights, yields the moisture by condensation, and so forms the column of clouds. Further, he finds a cause of some projectile action for the Kilauea lava-lakes and others in atmospheric air carried down by the descending lavas of the jets into the lava-lakes—as the crests of waves carry down air into the sea; and for the rest of it, or that producing the crater-fountains like those of Mt. Loa, he holds that the ascensive action in the conduit, after a time of quiet, suddenly overcomes resistances or stoppages that have come to exist in the conduit at depths below, and, as a consequence, the lavas, suddenly released, are thrown up in fountains, like the jets of mineral oil from an artesian boring.

I have already met part of the argument as to the absence of vapors of water, in my remarks on vesiculation, by showing (1) how extremely little moisture is needed to produce vesiculation (xxxv, 226), and (2) how much moisture hot air will dissolve and make invisible. It has also been stated (3) that if a Mt. Loa lava-stream has but a single fountain-head, as is generally supposed, though not proved, nearly all the vesiculation must occur at the source, so that for this reason and the heated air above it, the lava-stream should be vaporless, or appear so, except where there are fissures below for additional supply.†

Further (4), direct observation proves that the vapors come up out of the crater. They often rise directly from the

* Vestiges of the Molten Globe, pp. 75, 162–167, 175, 272–278, 309, 314.

† Mr. Green states, as an exceptional case, that at one place on the Mt. Loa flow of 1880–81, the lavas spread into a large lake, and vapors rose from it in great amount. This is good evidence of the existence there of a local supply of lavas through a fissure.

orifice of the crater, too low down for the air-current to have got into action; and in such cases there is an obvious source for the condensed moisture, and that is, the liquid lavas of the crater. Mr. Green expresses the fact well in the words (p. 169) "There is very often a large quantity of smoke seen to arise from the orifices of eruption, and this often spreads out in the higher regions of the atmosphere. There was a column, perhaps 500 feet wide and 10,000 high, arising from the orifice of 1859 when we pitched our tent along side it," at a point on the mountain 10,500 feet above the sea-level.

Further (5), the feeble amount of vapor observed by him in 1873 over the fountain in the summit-crater, so unlike what had existed a few days before, may have its explanation in the dryness of the atmosphere at the time. The air is generally dry at the summit, but must have its phases of unusual dryness, during which an unusual amount of escaping moisture would, for this reason, become invisible.

(7) The summit fountain is a combination of jets, each of which must have had its initiating projectile act; and it continues for weeks and months; and this is at variance with the evidence from Kilauea, which makes the ascensive action very gradually and quietly lifting, instead of projectile.

Finally (8) the cold atmospheric air carried down into a lava-lake by the jets could generate very little projectile power. The air, on entering the lavas, would encounter a temperature near 2000° F. if not beyond it, and hence the expansion would cause expulsion, or a speedy escape, in spite of any currents or intestine movements that might exist in the boiling cauldron.

For these reasons we may conclude that the old and generally accepted explanation which attributes the projectile action chiefly to water-vapor is not seriously invalidated by the ingenious suggestions brought forward by Mr. Green.

Part III.—ERUPTIONS OF KILAUEA AND MT. LOA.

In the following pages the subjects considered are: I. The characteristics and causes of eruptions; II. Metamorphism under volcanic action; III. The form of Mt. Loa as a result of its eruptions; IV. The relations of Kilauea to Mt. Loa; V. General volcanic phenomena.

Under the head of Eruptions, the principal topics are: the kinds; the places of outbreak; the causes of eruptions; the characters of the lava streams; the positions and origin of the subordinate lateral cones.

I. Characteristics and Causes of Eruptions.

Eruptions are of two kinds: (1) *Non-explosive eruptions*, or quiet outflows, seismically attended or not; and (2) *Explosive eruptions*, or catastrophic upthrows. Both kinds are exemplified in Hawaiian volcanic history. There are also (3) combinations of the two kinds in volcanic regions.

1. ORDINARY OR NON-EXPLOSIVE ERUPTIONS.

Kilauea and Mt. Loa are alike, as has been shown, in (1) their mode of work; (2) the southward position, in the crater, of the point of greatest activity; and (3) the general features of their eruptions. But in amount of eruptive work the summit crater is far ahead of Kilauea, and, in fact, it leads the world. Kilauea has had but one subaerial outflow of any magnitude in the last fifty years, and that only twelve miles long. Mt. Loa, on the contrary, although nearly 13,000 feet up to the bottom of the crater, has had in the same time only one of its eight less than twelve miles long, and several between twenty and thirty-five; and it has reached its height without a loss of eruptive power. It is reasonable, therefore, that Mt. Loa should have most instruction to give about outflows.

1. *Heights and positions of the places of outbreak.*

1. *The Heights.*—The place of outbreak of a Mt. Loa eruption may have any height from the summit to levels far below the sea-level; and this "far below" may be, as the map on p. 82 shows, 17,250 feet down before reaching the actual foot of the eastern slope. The heights of known occurrence are mentioned in the table on p. 83. The completion of the topographical survey of Hawaii, now in progress under the government, will before long give more correct figures. The height of the source of the one Kilauea outflow, that of 1840, or rather of the spot where it appears to begin, is 1244 feet (Wilkes).

In each of the cases of eruption, fractures were made near the summit which extended down the mountain, with only small discharges along them when any, to the place of chief outflow. In some cases, fissures have opened on the brink of the crater and let out lavas; but all the large outflows of modern time have come from points a thousand feet or more below the summit.

2. *Relations between the positions of the places of outbreak and the diameters of the craters.*—The course of the northern half of the longer diameter of the summit crater is about N. 35° E., and that of the southern half, about N. 20° E. or

S. 20° W., as marked on the upper and lower margin of Plate II. Four of the largest lava-streams of Mt. Loa, those of 1843, 1852, 1855 and 1880, and two others to the south, those of 1868 and 1887, have their places of outbreak nearly in the line of the respective halves of *the longer diameter*. Again, three of the eruptions, those of 1851, 1859 and 1877, broke out on the west side of the summit, nearly in the line of *the shorter diameter*, or between the summit and Hualalai.

There is here probable evidence of a dependence of the eruptions to some extent on the two great fissure-lines upon or about which the mountain's foundations were laid.

The direction of the longer diameter of Kilauea is about N. 50° E.–S. 50° W. The chief course of eruptions, as on Mt. Loa, is marked by a line of fissures and ejections running west-southwestward in the direction of the longer diameter. But the large outflow of 1840, and the fissures leading to it, instead of pointing toward the crater, have a course nearly *parallel* to the longer diameter, but fifteen miles south of the Kilauea line. This is seen on the map, page 82, but better on Plate I, the stream being the one near the east cape.

2. *Causes of Eruptions.*

1. *State of readiness for an Eruption.*—The *ordinary quiet* work of the craters has been shown to be carried on by—

(1) The ascensive force of the conduit lavas; this force producing (1) a slow rise in the liquid rock from depths below; and (2) a raising of the crater's bottom.

(2) The elastic force of rising, expanding and escaping vapors; producing jets and fountains in the lava-lakes; overflows or ejections spreading the lavas over the crater's bottom; vesiculation of the lava and consequent increase of its bulk.

Other causes have been mentioned as occasionally in action (xxxv, 228), but as not essential to the chief results.

After a season of this ordinary activity, with more or less gradual increase of intensity, a state of readiness for an eruption and its determining conditions have been reached. This has happened when the lava has risen, through these agencies, to what might be called *high-lava mark;* a level some hundreds of feet above low-lava mark or the low level occasioned by the preceding discharge.

2. *Action needed for an Eruption.*—After this preparation nothing is needed for an eruption but an agency of sufficient force to break the lava-conduit; for if broken seriously the lava will run out, and therein is an eruption or discharge.

Neither of the agencies carrying on the ordinary quiet work of the volcano has shown itself capable, during historic time, that is, since 1822, of breaking the lava-conduit for a discharge.

The escaping vapors have spent their force mostly in making jets and fountains and feeble outflows; and still more quiet has been the work of the ascensive force. Eruptions have been a sequel to years of this quiet work, but not a direct effect of the action.

3. *Agency of Earthquakes.*—Earthquakes have often been considered an effective agent in eruptions. But during the past sixty-five years only two of the eruptions of Mt. Loa and one of Kilauea have been introduced or attended by noticeable earthquakes. The eruptive agent in both volcanoes has in general worked quietly, "as quietly as the moon rises," says one writer, without much exaggeration. The star-like light on Mt. Loa has been followed soon by a stronger glow; and, accompanying this, a rising of clouds into heaps and lofty columns. After a day or two or three, the summit-light having disappeared, the flow has begun one, two, or three thousand feet below the top; and a line of light has then slowly lengthened down the mountain for twenty or thirty miles; and all this, quietly. It is the grandest of volcanic work with the least possible display of force.

The facts connected with the two eruptions of Mt. Loa and one of Kilauea, that were attended by earthquakes, merit special review in this place because they teach what earthquakes may do, and by what means. The three occurred in the years 1868 and 1887.

On a Friday in 1868, March 27 (p. 24 and xxxiv, 91), a light was seen on the mountain and feeble earthshocks occurred. Only slight eruptions followed. Then, in accordance with the ordinary rule, these first fires at the summit disappeared. But the earthquakes increased in violence—not about the summit, but far to the southward, within the lower three or four thousand feet of the mountain. And they continued increasing until that "terrible shock" of Thursday, April 2d. Five days later, April 7th, the lava burst out from an opened fissure at a point, 23 *miles distant from the summit* and only 10 or 11 from the sea-coast.

It is here manifest that the earthquakes had nothing to do with *preparing* for the eruption; they were too late for this. It is possible that the first break near the summit anticipated the first earthshock But below, in the region of most violent disturbance, greater fissures were opened, the profoundest probably at the very time of that "terrible shock;" and as soon after as the subterranean passage could be made—about five days—the lava from the broken lava-conduit or reservoir made its appearance at the surface and hurried down the mountain to the sea. But at the sea-border and elsewhere the fissures were probably ahead of the lava, according to Professor

C. H. Hitchcock, and gave it exit nearly all the way, occasioning their rapid progress seaward.

Here then it is clear what the earthquakes did to produce the eruption. They, or the cause generating them, broke a hole into the conduit, and the lava escaped. The lava of the conduit was not thrown into commotion or projected to great altitudes at the summit; instead, it sank out of sight, following the rent to the surface far down the mountain. These events were repeated almost precisely in the Mt. Loa eruption of 1887. The locus of the outflow and of the earthquakes in both cases was far south in southern Hawaii, and the two streams followed near and parallel lines; the chief difference between them was in the higher outlet in 1887 by 2500 or 3000 feet (see map, page 82).

The earthquake eruption of Kilauea was coincident with the first of the two Mt. Loa eruptions in April, 1868. The earthquakes were the same identical earthquakes; and that "terrible shock" of April 2d was for each the special discharging agent. Immediately after the shock the fires of Kilauea, before unusually active,* commenced to decline; by night of that Thursday, all the burning cones, by night of Saturday all the smaller lava-lakes, and by Sunday night, the great South Lake, had become extinct. And then, the lavas having run off, half the floor of the crater sunk down 300 feet.

A genetic connection between the earthquake disturbance and the eruption cannot be doubted. The earthquakes came after the crater had reached a state of unusual activity, and hence could have taken no part in the preparation. They simply discharged the lava by breaking the conduit that held it.

Moreover, the earthquakes which thus emptied Kilauea were of Mt. Loa origin; they had their center thirty miles or more west of Kilauea, and were made through the Mt. Loa fires. It is a case, therefore, of one mountain-volcano accidentally discharging the conduit-lava of another. The work was simply a fracturing of the mountain in different directions; for the island was violently shaken from the west side to Hilo on the east coast; and, in the general fracturing, the two volcanic conduits were broken at once, an accident not likely to often happen.

It is also to be noted that *the earthquakes were of local or volcanic origin.* This is established by the fact that only two of the heaviest shocks reached westward to Honolulu on Oahu

* Dr. Hillebrand states that for two months previous to the eruption there were eight lava-lakes in the bottom; and until March 17th, a very active blow-hole in the northwest corner, where "large masses of vapor were thrown off as from a steam engine" on Thursday, April 2d, after the earthquake, there were fearful detonations in the crater, and portions of the wall tumbled in; and then began the decline.

(p. 24); and these so feebly that they did not make themselves generally felt in that city (see map, p. 82). The depth of the oceanic depression between Hawaii and Oahu, which is only 500 fathoms where least (between Hawaii and Maui), was sufficient to stop off the vibrations. Further as in the Mt. Loa eruptions, no increase of projectile action was occasioned in the crater by the earthquake disturbance; the lavas simply, in the quietest way, ran off, leaving the crater empty, still and dark.

A mountain having within it two great regions of liquid lava thousands of feet in height, each at a temperature above 2000° F., and with subterranean waters abundant, at least through the lower two-thirds of the altitude, is well fitted for the production of eruptive crises; and it is remarkable that the eruptions of 1868 and 1887 are the only ones seismically occasioned, or attended, in the past 65 years; and, further, that in these eruptions, although among the most violent on record, the craters were wholly free from explosive action.

The violent earthquakes of 1868 and 1887 accomplished nothing so far as the eruptions were concerned that is not effected on Hawaii in four eruptions out of five without them. The greatest of the eruptions have had no such aid. In the preparation for a discharge, the mountain has reached a dangerous state, because of the elongation upward of the fire column; then the fracturing agency has done its work; earthquakes are only a possible incident. With or without them, the conditions and results are the same; for vibrations necessarily attend fracturing, and earthquakes are simply the stronger or perceptible earthshocks.

4. *The rupturing and ejecting forces.*—The chief cause of the rupturing is no doubt the elastic force of suddenly generated vapor. So far this is an accepted explanation. As to the conditions under which this vapor is generated, there is not so general agreement.

The facts show, *first*, that on Hawaii the vapors are not suddenly generated *within* the conduit; for in the event, the lavas slink away from the crater, instead of dashing up wildly to great heights. If not generated *within*, it must be *without*, and the most probable region is that of the hot exterior of the conduit, or the hot rocks encasing the liquid column, or else fissures or local fire-places adjoining it. In this view the fracturing depends on the sudden access of subterranean waters to this outside region of great heat.

Secondly, the evidence proves that the force makes a fissure or fissures for the discharge of the lava without giving the waters entrance into the conduit. The pressure of the elastic vapor expends itself in breaking the sides of the mountain, and

only under the most extraordinary circumstances is the water forced into the lava-column. The earthquakes of 1868 were an exhibition of the power generated; and hardly less so is the noiseless fracturing for the greatest of eruptions.

Some erupting action comes from hydrostatic pressure. But the fact that the fissures first open quite near the summit of Mt. Loa is evidence that pressure from this source is the least efficient agent.

Why southwestern Hawaii should be especially liable to violent earthshocks in connection with its outflows is not wholly clear. But there are three significant facts bearing on the question.

(1) The southern half of the longer diameter of the Mt. Loa crater, and fissures from it down the mountain, point directly to the place of outbreaks of 1868 and 1887, the probable localities of the earthquake epicentra of those years.

(2) The longer diameter of Kilauea, with a long line of fissures, having the trend S. 52° W., points nearly to the same region of outbreak; so that the *two diametral lines, the Mt. Loa and the Kilauea, there intersect.* (See map, p. 82 and Plate I.)

(3) These lines have long been common directions of fractures and eruptions, as shown by the old lavas of the surface as well as by existing lines of fractures.

This divergence between the courses of the longer diameters of the craters of Mt. Loa and Kilauea comes up again for consideration in the remarks on the relations of the two volcanoes.

In the eruptions the *ejecting* force may be feeble or null; for the lava may flow out, when the source favors it, simply through gravity; but, in general, ejection is pushed forward, (1) by the elastic vapors within the lava-column; by vapors generated outside, like those producing eruptions; and by hydrostatic pressure.

The first of these causes is the source of the high fountains in the summit crater; and the summit effects indicate that it should have great propelling power at places of outflow. The fountains at the outflows have hitherto been attributed to hydrostatic pressure; but the two causes must here act together, and it is impossible to say from present knowledge which preponderates.

Fountains attended the outbreak at the eruptions of 1852, 1859, 1868 and 1887 (pp. 19, 22, 24, 32,); and it is probably that examination at other times would have added one or two to the list. The lengths of the lava-column (A) above the place of outbreak at these eruptions, and (B) the reported heights of the fountains in feet, are as follows:

	1852	1859	1868	1887
A	2500	3000	10,000	7000
B	200–700	300–400	200—; 600?	200? 80.

Owing to the height of the column above the level of the outlet in 1868, 10,000 feet, the hydrostatic pressure should then have been greatest; the force from the vapors in the lava-column, least; and the friction in the very long passage-way from the broken conduit, the most obstructing.

The second source of ejecting and fracturing pressure mentioned above is the probable origin of the fractures which sometimes cut through the walls of a crater to the summit; and if the vapors producing the pressure are generated over a source of liquid lava, the fissures would necessarily become injected with lava which might flow out above in a stream. Cases of this kind about Kilauea occurred at the eruptions of 1832 and 1868, (xxxiii, 445, xxxiv, 92); and Mr. W. T. Brigham and Rev. J. M. Alexander mention others, of uncertain date, about the summit crater.

Mr. Alexander speaks of a "cataract of lava" descending the walls into the crater from the summit; and farther south, of two other similar cataracts; and at the summit he found the deep fissure from which the cataracts had been supplied with lava, and ascertained that it had also poured out an immense stream northward upon the first plateau and thence southward into the central crater. "On the southwest side of the crater there had been another eruption from fissures that were still smoking, and the eruption had sent a great stream southward toward Kahuku and had also poured cataracts into the south crater from all sides." "The flows were from some of the highest parts of the brim;" and "from the brink there had been large flows down the mountains." "These outbreaks from fissures around the rim indicate that the lava has rather poured into the crater than out of it; and also that it has flowed from such fissures in vast streams down the mountain side." These cases perhaps date from the eruption of 1880, the last that preceded Mr. Alexander's investigation of the crater.

Such events if attending an eruption belong to its very beginning before the lava is drawn off from the crater. They may occur at other times; that they do so is not yet certain, except in a small way within Kilauea, about the lava-lakes. (xxxv, 228).

3. *The Outflows and the circumstances attending them.*

1. *The source.*—An outflow of lava may commence as a stream or as a fountain. In either case, the pent-up vapors of the lava-column make their forcible escape with the lava; and a cone

of solidifided lava more or less scoriaceous is usually formed about the vent by the pericentric action. These cones are mentioned in the descriptions of all the outbreaks, not excepting that of 1880, which was visited by Rev. E. P. Baker. Large deposits of cinders, or a light scoria, are sometimes distributed over the adjoining region, and Pélé's hair is also a common product; the former where the lava is thrown up in fountains and partially cools exteriorly as it falls (p. 28), and the latter from the action of either the fountains or the low jets (xxxv, 221).

The summit crater of Mt. Loa, unlike Kilauea, is often left, after an eruption, with one or more cinder-cones on the bottom; the larger of them usually in the southern portion of the crater. They are probably made from the lavas as the heat declines with the first commencing movements of an eruption.

2. *Rate of flow.*—The great flow of 1852, so grand in its fountains and twenty miles long, was finished in twenty days; this gives, for its mean rate of progress, a mile a day. The flow of 1859, thirty-three miles long, occupied only eight days, which corresponds to a rate of four miles a day on a mean slope of 1 foot in 15. The thirty miles to Hilo in the stream of 1880–81 took nine months; and the mean slope was 1 foot in 13 or about 5 degrees.

The general conditions in the flow of a great stream, its obstructions and modes of overcoming them, are well described by Mr. Coan (p. 20). As to actual *rate* of flow, we want more precise facts. It is difficult to reconcile the facts stated on these points; and especially the various velocities attributed to the different portions of a flowing stream, for example: the reported rate in one of the tunnels of "40 miles an hour" with a rate for the front of the flow of "one mile a week." The difficulty is still great if we suppose the 40 to be only 10, and whatever the obstructions along the front. The conditions are those of a discharging faucet, and the flow below is that of the liquid after its escape spreading widely over a rough surface.

The many openings through the crust of a stream into the tunnels which give out vapors, and often have the shape of jagged cones, suggest the possibility that a fissure may exist beneath in these and similar places for the discharge of lava and vapors. But the idea that such fissures generally underlie a lava stream (which I formerly thought probable) is opposed by Mr. Coan; and there are not facts to sustain it except for the Mt. Loa stream of 1868 and the Kilauea for 1840.

The tunnels of a stream, made by a crusting of the surface while the lava continues flowing beneath, have a smooth, somewhat glassy or enamelled interior, with horizontal flutings and mouldings which were made by the moving lava. In a tunnel

of the stream of 1880–81, near Hilo, which I visited under the guidance of Rev. E. P. Baker, one of the lines of mouldings had the form and position along the side of a solid handsomely modeled bench, indicating that the lava had encountered an outside obstacle in a projecting angle of cooled rock. This tunnel had a varying height of 4 to 8 feet and a general width of about 30 feet, but also some branchings and lateral expansions of large extent. The roof was two to six feet thick. The smoothness of the interior is favorable to a high velocity. The small capacity of the one entered near Hilo suggested the following queries: How much of the lava of a stream a mile wide runs in tunnels? Does the little width of the tunnel, and thereby of the supply stream, account for the difference of velocity in the tunnels and at the front? if so, the exit should be as free as that from a faucet, or the arrangements would not work. How many such tunnels exist side by side? Does a single tunnel continue on for 20 or 30 miles as an uninterrupted lava duct? We should infer that for a large stream the system of tunnels would become a very complicated one.

Whatever doubts exist as to rate of flow, there is none as to the extreme liquidity of the Mt. Loa lava, and its equalling if not exceeding that of Kilauea.

3. *The amount of Lava discharged.*—There are no data as regards the breadth or the depth of the streams, for a satisfactory calculation of the amount discharged. The depths might at many points be ascertained from the holes left by burnt trunks of trees. We can now only make a supposition.

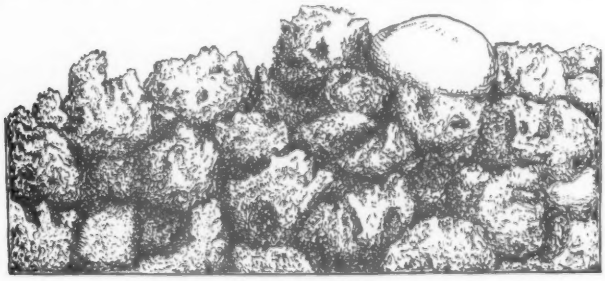
The flow of 1852 was 20 miles long. If we suppose the mean depth of the stream to be 20 feet, and the mean width, 5000 feet, the amount of lava it contains would be 10,560,000,000 cubic feet. Supposing the lava-column to have the mean diameter of the central part of the summit crater, 9000 feet, it would contain, down to a depth of 2500 feet, (the place of discharge for that eruption) nearly 160,000,000,000 cubic feet of lava, or fifteen times as much as was discharged. Accordingly, the discharge, if the above figures represent the whole amount, would have drawn off less than 200 feet in depth from the lava conduit; and a rise of 200 feet again would have made the mountain ready for another discharge. The calculation is suggestive, though otherwise of little value. In addition to the other uncertainties we know nothing as to how much of a discharge passes off into subterranean cavities; which may be very large, for the great eruption of Kilauea in 1832 has little to show over the surface of the island.

Whatever the amount of lava or of height that is lost by the lava-column at an eruption, it has taken, as has been shown, but a very short time in several cases, to fill up again for a new dis-

charge. I repeat here that after the eruption of 1852, which produced a stream 20 miles long, had closed, the lofty volcano was ready in only 3½ years for a 26-mile flow, that of 1855; and in 3½ years more, for another still longer, that of 1859, 33 miles in length of stream: which is brisk work for the great old mountain. According to these facts the lava-column had risen, after the eruptions, at the rate of at least 100 feet a year so as to reach again the bottom of the crater and be ready for another discharge.

4. *Kinds of Lava-Streams. Pahoehoe and aa.*—The ordinary smooth-surfaced lava-stream, the pahoehoe, needs here no further description. The *aa*-stream is less often seen in process of formation and is more difficult to understand. With reference to an explanation of its origin, I repeat here from volume xxxiv the characteristics of the typical kind (not of the thinner streams that approximate to the pahoehoe), and reproduce also the sketch of a portion of one to aid the conception of its roughness: the reader's conception of it will be feeble at the best if he has not had a view of chaos already.

a. The characters of the cooled aa-stream: (1) a mass of rough blocks one foot and less to 1000 cubic feet in size, loosely piled together to a height of twenty to forty feet above the general level; (2) the blocks bristled with points but not scoriaceous, and less vesiculate than most of the pahoehoe;



Portion of an aa lava-stream.

(3) the material rather brittle, and consequently, when made up of small blocks or pieces easily broken down to a flat surface for the site of a house; (4) often aa in one part, and pahoehoe for the rest—either the chief part; (5) from one outbreak a pahoehoe-stream in one direction and an aa-stream in another.

b. The constitution and condition when in motion: (1) a mass of rough blocks outside, precisely like the cooled; (2) the motion extremely slow, indicating a semifluid condition beneath; (3) a red heat often in front among the blocks; (4)

fused rock seldom exuding; (5) the blocks of the upper part of the front, as the stream creeps on, keep tumbling down the high slope, owing to retardation at bottom from friction, and thus a rolling action in the front part.

The aa-field, owing to its crevices and shaded recesses, retains moisture, and decomposition at surface early commences, which favors germination of seeds; and often the stream, as I am informed by Mr. Baker, becomes forest-covered when the pahoehoe alongside remains bare.

One of the best published descriptions of an aa-flow is that of Judge Hitchcock (p. 31) which says: "Along the whole line of the advance, the stream, twelve to thirty-five feet in height, was one crash of rolling, sliding, tumbling, red-hot rock, no liquid rock being in sight; with no explosions, but a tremendous roaring like ten thousand blast furnaces all at work at once." Mr. Baker writes (letter of February, 1888): "I have stood by a wholly molten stream of lava which miles below was cooling into aa."

Under the restrictions of such facts the aa cannot be explained by referring it to simply a partial cooling of a stream and then a breaking up of the crust on a new accession of flowing lava—a common explanation; for there is no evidence of a crust from surface-cooling analogous to that of pahoehoe. It is not dependent on the mineral constitution of the lava; for one and the same stream may take either condition; and adjoining fields near Punaluu are at opposite extremes as to the amount of chrysolite.

The *first* conclusion we may draw, in view of the facts, and especially the abrupt transitions from aa to pahoehoe and the reverse in the flowing stream, and the independence of kind of lava, is that the difference must be connected with some condition in the region flowed over; and, the *second*, that where the transition from one kind of stream to the other occurs, the conditions must be such as will allow of extreme liquidity in one part (the pahoehoe), and occasion imperfect liquidity or a pasty state in the other (the aa).

It follows also from the size and rough character of the blocks of lava, *thirdly*, that in an aa stream the lava must have been subjected to some deeply-acting cooling agency to have made a crust thick enough for blocks 10 to 20 feet and more in dimensions—far thicker than the crust over the tunnels in a pahoehoe stream. *Fourthly*, that the cooling was not from above downward, as in the pahoehoe, for there are no remains of a crust in the true aa field, but largely from below upward; and thence comes the absence of a crust and of the usual amount of vesiculation.

These four conclusions appear to lead directly to a *fifth:*

that the region flowed over and making aa was one having more or less of subterranean moisture, since only moisture could produce the partial cooling required; not a superficial stream of water that the lava could evaporate and so put out of its way, but deeper and more widely spread moisture; and not too much for the quiet work of molecular imbibition and thereby of cooling and fracturing, with sometimes a "tremendous roaring like ten thousand blast furnaces." The aa near Hilo, of which I have spoken, was over a valley depression beneath which such an amount of moisture may well have existed. Another was along the foot of the meeting slopes of Mt. Loa and Kilauea, west-southwest of Kilauea. But my own observations were too brief to authorize a positive opinion as to the influence of the form of the surface in these cases; and in others, according to the descriptions, the surface covered by the aa is not always depressed.

There must be more or less moisture in the dark recesses of Mt. Loa. The cold summit will find enough in the air to condense at most seasons. And the percolating rains must keep the recesses damp and even make standing water wherever the rocky layers favor it. With subterranean moisture a hundred yards more or less beneath the broad lava-bed, the generated vapors would ascend into and through the liquid mass, cooling it thus from below, yet not so much the hotter bottom which receives new supplies of lava, as the portion above. The part solidified would become shattered or broken up by the tearing steam and by contraction from cooling; and, at the same time, the flow at bottom would displace and tumble together the great and small masses, giving the pile height because of the jagged forms of the blocks and the cavernous recesses left among them. This view appears to meet the demands of the facts I have observed, and all others so far as they have been published. But I present it only as a suggestion.

On this view an aa stream is literally an arate or ploughed up lava-stream; a stream ploughed up from near its bottom, so that, although vesiculated, the surface vesiculation fails, as was well shown in the stream of 1880–81 near Hilo, and in all the other cases I examined.

Dome-shaped bulges in a cooled lava stream would naturally be common over the pahoehoe part of it where the stream begins to pass to the aa condition.

The *bomb-like masses*, concentric in structure, observed over aa streams (xxxiv, 364, and in the figure on page 100), varying from an inch to a mean diameter of 10 feet, appear to be produced through the rolling movement in the forward portion of the advancing aa stream, due to friction at bottom (p. 101). They are often a heap of fragments of scoria inside with a

crust of solid lava outside, or consist of a series of concentric layers.

Dr. H. J. Johnston Lavis, who has studied with much care the Vesuvian lavas and eruptions, shows in his paper on "Fragmentary Ejectamenta of Volcanoes,"* that the "volcanic bombs" of writers on European volcanoes are not bombs any more than those of Mt. Loa; that they were not projected into the air; that they occur scattered over lava streams in great numbers when the adjoining country is free from them, and occur within lava streams; that they vary in size from a walnut to some cubic yards, and yet have often a thin shell and friable nucleus; that they "occur most commonly by far on the surface of lava-streams whose surface is rough and scoriaceous, instead of corded." He regards them as formed of lapilli that fell upon the flowing lava, and "in consequence of its forward motion became incorporated with it, and may undergo partial fusion, but usually congeal around themselves a coating of the parts in which they are involved." The description shows that the bomb-like masses of Hawaii are essentially identical in origin with the "volcanic bombs" of Europe. *Ejected blocks* are, as Dr. Johnston-Lavis remarks, wholly different in origin.

4. *Lateral Cones.*

Lateral cones are a frequent result of eruptions on Hawaii and the other islands of the group, although the lavas are basaltic. They occur, as in other volcanic regions, along the courses of fissures; along a flow of lava where fissures for supplying lavas are underneath it; and also in and about the summit crater. Whether they consist of lava-streams, or of cinders (lapilli) depends on the supply of heat as well as of lava in the vent (xxxv, 28); and whether the cinders make cinder-cones or tufa cones, on the supply of moisture connected with the eruption, much descending moisture giving a mud-like flow to the ejected cinders, whence the low angle and saucer-like crater of the tufa-cone.

They appear to be most common over the lower portion of a lava-stream, toward or along the sea-border; and it may be that this is due to the presence of more subterranean waters about the lower or foot slopes. A lateral cone of either of the three kinds is good evidence of a fissure beneath as a source of the ejected and pericentrically deposited material; and this evidence from them gives their occurrence especial interest. Where a stream of lava enters the sea and makes a cone of cinders or lava, there must be a fissure to supply the lavas and

* Proc. Geologist's Assoc., London, ix, No. 6.

projectile vapors, and thus to produce the upward throw of cinders and the pericentric deposition and stratification which are the marked features of a lateral cone. No such shape or structure can come from the simple discharge of a lava-stream into the sea, however rapid its progress; for this merely puts the fragments that are made at the disposal of the waves or currents along the coast, and the heaps piled up will be such as the action of waves and currents may make elsewhere. It cannot imitate successfully the pericentric work of the volcano. For this work, a center of ejection, acting for successive days or weeks, is required.

2. EXPLOSIVE ERUPTIONS.

All the eruptions of Mt. Loa and Kilauea within the last 65 years, the period of actual history, have been, as has been stated of the ordinary kind, that is quiet outflows. At each, the lavas of the crater have simply quit work and sunk out of sight; and the discharge thus begun, with the consequent down-plunge of the undermined floor, was nearly all there was of eruption so far as the crater was concerned.

But traditional history gives hints of an eruption in 1789—a century back within a year—of another kind; and the results are visible over the region around the crater of Kilauea, as already described (xxxiv, 359). Similar evidences exist of an explosive eruption in the summit crater, as may be inferred from the descriptions of Mr. Brigham (p. 23) and J. M. Alexander (p. 31), as well as the earlier of Captain Wilkes,* and also in that of Hualalai.

In the cases here referred to, the ejected material includes solid masses of the basalt, much of it very compact, and some of the blocks 50 to 100 cubic feet in size. For such work, instead of a cessation of the ordinary projectile action of the crater and a quiet discharge of the lavas when the eruption began, there must have been an enormous increase of projectile power, with great rendings of the rocks within reach of the up-thrust action. The eruption was not a quiet outflow, but a catastrophic up-throw. Whether accompanied or not by an outflow of lava is unknown.

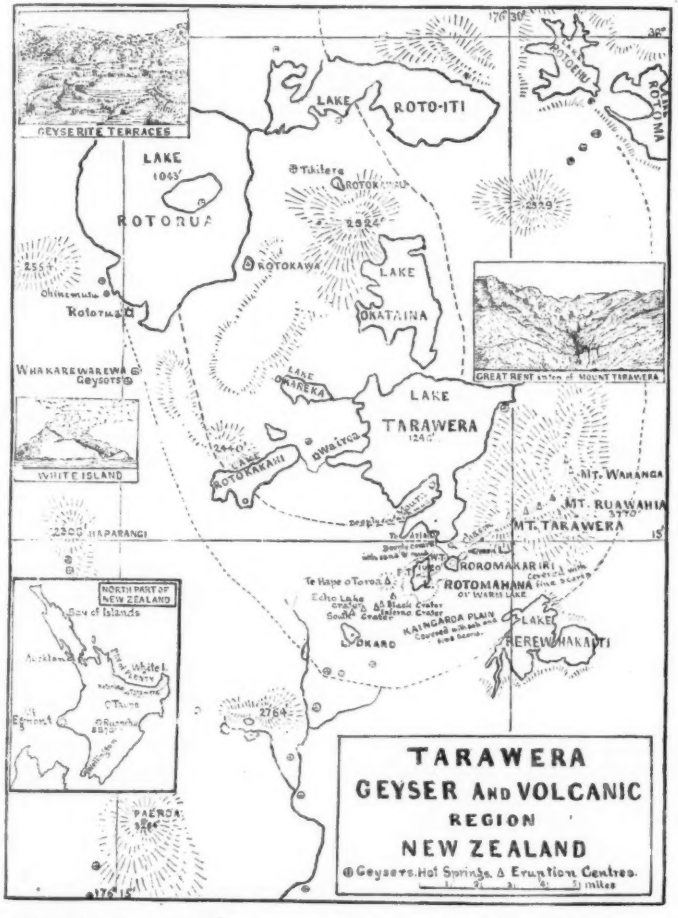
Examples of explosive eruptions from Tarawera in New Zealand, and Krakatoa an island just west of Java, will make clear what is meant distinctively by an explosive eruption.

In 1886, in the Tarawera geyser region after some earthshocks, a projectile eruption of terrific violence and incessant

* Wilkes speaks of large bowlders of a grayish basalt at the summit which had apparently been ejected from the crater (p. 159).

The precise date of the Kilauea eruption is in some doubt.

detonations began. Scoria and volcanic ashes or sand were thrown to a great height, that drifted with the wind and covered the country thickly and far away with ashes, making darkness, over a breadth of several miles, all the way to the sea in the Bay of Plenty. The height as seen from Auckland, 130



miles distant, according to a measurement by Mr. Vickermann of the Survey Department of New Zealand, was 44,700 feet. The eruption was ended and the clouds of dust gone in six hours. The work was done so quickly and fiercely that no cinder cones were made by deposits about the place of chief discharge. No outflow of lavas took place.

The accompanying map and explanations will make the remarkable Tarawera events more intelligible.* It represents the Tarawera geyser region, its lakes, mountains, and other features. A small map to the left shows the northern New Zealand island, and the site of Tarawera in the N. 35° E. volcanic line of Ruapehu, Lake Taupo and White Island; and White Island is represented in its usual steaming condition in a sketch just above. The line of the eruption in 1886 extended in a N.E.-S.W. course from Lake Okaro through Mt. Tarawera and Mt. Wahanga. Lake Rotomahana at the time of the eruption was emptied and converted into a region of craters. This lake, previous to the eruption, had on either side, a geyser basin and one of the famous geyserite terraces of New Zealand; the "Pink terrace" on the west (PT on the map), and the larger and more beautiful "White terrace" (WT) on the northeast side with the geyser Te Tarata at its head. The outflowing waters of Te Tarata, descending the gently sloping surface to the lake, had covered an area eleven and a half acres in extent with its siliceous (or geyserite) depositions, forming a descending succession of whitish cream-colored and almost porcelain-like terraces. A view of a portion of the terrace is given in the left upper corner of the map. Both terraces were buried in volcanic mud and ashes, a mud volcano displacing the geyser basin. A sketch to the left represents (from a photograph by Mr. C. Spencer), the region of the "great chasm," 200 yards and more wide, made in the Tarawera range at the outbreak; and the map gives its position, and also the positions of the several centers of eruption along the region. The outer dotted line on the map encloses the part of the Tarawera region that was covered with volcanic ashes, mud and scoria, and the inner, the portion of the larger area that was buried beneath mud; and the latter includes the buried villages of Te Ariki, Moura and Wairoa, where there was destruction of life, as well as a general obliteration of houses. Subsidences continued to take place along the great opened fissures for weeks after the eruption had ceased.

At Krakatoa, in 1883, the projectile discharge was equally sudden, and far more terrible and destructive. The height to which the dust was carried was made by Professor Verbeck 50,000 feet. It began in the early morning of one day, made day into night (by its ejections of ashes) for 36 hours, and left the sky clear by the close of the next day. Nothing is said of an outflow of lavas.

The earthquakes at Tarawera were not violent; they were felt to a distance of 50 or 60 miles only; and a dozen miles from Tarawera Mountain, at Rotorua, on the geyser plains, no shock was able to upset a chimney or jar down crockery from

* The facts here given are from an account of the eruption by T. W. Leys, 56 pp. 8vo, with maps and other illustrations, Auckland, New Zealand, and the Report of S. Percy Smith, Assistant Surveyor General, 84 pp. 8vo, Wellington. The height of the ejections above given is cited from the latter work, page 29.

a shelf. They were manifestly local, and had their center near the surface—an effect, not a cause; and they thus prove that the immediate cause of the eruption was local. The facts as to the Krakatoa earthquakes are similar. The deafening roar in each was made chiefly by the violent projectile action, the incessant detonations and the thunderings of a storm.

Such eruptions are of a wholly different cast from the ordinary outbreaks and discharges of Hawaii. The projectile agent must gain access to the conduit lavas to produce such extraordinary violence.

The eruption of Tarawera Mountain was probably brought about by the opening of a fissure that let subterranean waters *into* the reservoir of lavas; for Lake Rotomahana, situated on the line of fracture and only three or four miles distant, lost its waters, and probably in the process of supplying water for the projectile work. The volcanic mountain had been long extinct; but the widely distributed geysers and boiling springs were testimony to the existence of liquid lavas just below the reach of descending atmospheric waters. The geyser lakes of Rotorua and other localities became hotter during the night of the eruption and continued so afterward. Under such conditions an old volcanic mountain, perhaps hollow from former discharges, might be burst open again. Had the ingressing waters passed into the lava-reservoir *at a great depth* below the surface, the generated vapors would necessarily have added outflows of lava to the projectile discharge.

The volcano of Krakatoa, was probably started into action by a similar incursion, but of marine waters.

In both cases there were enormous chasms and crater-like depressions made, with a loss of the old foundations, and of the rocks that occupied the depressions. But the facts, while they include the projection of large stones over the vicinity, show positively that the stones were few compared with what would be needed to fill the great cavities left in the region. The explosive eruption blew to great heights fragments of the liquid lavas in the shape of scoria and sand or ashes, but did not blow off the solid rocks of the mountain. The disappearance of these and the making of the cavities are explained by the engulfment or down-plunge of material *to fill the space left empty* by the projectile discharges.

An *explosive eruption* is then simply one in which the projectile action, instead of ceasing at the time of eruption, becomes enormously increased; in which the erupting agent, instead of being roused to action outside of the lava-conduit, gains access to its interior, and hence the terrific boiler-like explosion.

For further explanation I repeat that the *ordinary activity*

of a volcano consists in the more or less high projection of cinders or of liquid lavas, with usually a great increase in the height as the crisis of an eruption approaches. In such action, there is nothing of the explosive work above described; neither is it entitled to be called a state of eruption; it is only a state of activity. Stromboli is perpetually at work in the *ordinary* way, with great variations in activity, "exhibiting the nature of volcanic action in its true light;" but it is not in "perpetual eruption;" no true eruption of this volcano, non-explosive or explosive, has been recorded in recent times. A volcano often gasps out its life in cinder ejections; for this is the meaning of the summit cinder cones of Kea, Hualalai, and Haleakala. It is still true, however, that cases occur in which it is difficult to decide whether the condition is that of ordinary activity or of true eruption.

The results of the projectile eruption of Kilauea, mentioned in the earlier part of this paper (xxxiv, 359–361), need not be here repeated. We learn from the deposits made by it that the eruption began in bombarding style—the projection of great stones to a distance of one to two miles, ranging to a height a thousand or more feet above the place of discharge; and ended in a widely extended shower of scoria and ashes. The finer material, besides covering all the borders of Kilauea, spread for miles to the southeastward, southward and southwestward. It constitutes, as I learn from Mr. Baker, the sand of the Kau "desert" described as ten by fifteen miles in area, and makes the bed, for six or eight miles, of an excellent carriage road between the crater and the ranch nearly half-way to Keauhou.

The evidence that the great stones were from the throat of the lava-conduit and not from the walls of the crater consists in their comprising, both east and west of Kilauea, kinds not found in the walls; and also many blocks of lava whose vesicles are lined with minute crystals of pyroxene and a plagioclase feldspar (as determined by Professor E. S. Dana), which are proof of subjection to long-continued heat. The walls of Kilauea are out of the reach of such upthrust or projectile action.

The explosive eruption of the summit-crater is of unknown date. As some of the ejected stones are fifty pounds to a ton in weight, it was probably similar in character to that of Kilauea; but the facts need further study.

Explosive eruptions at Kilauea and Mt. Loa are exceptional occurrences. In my examinations of the well-stratified walls of Kilauea I found evidence only of layers of lava—that is of old lava streams. But thin beds of stones and scoria might occur at intervals without making much impression on the

mountain or leaving very apparent traces in the walls. The summit crater, as described by visitors, has, like Kilauea, walls made of the edges of lava streams, without intercalations of prominent beds of scoria or other fragmental material.

II. Metamorphism an Effect of Volcanic Conditions.

The projected rocks of the region about Kilauea are a prominent source of evidence as to metamorphism by means of volcanic heat—as remarked on page 289 of volume xxxv; and other facts of like import are derived from the lava-stream tunnels and caverns. The rocks referred to, and those also of the lavas generally, as well as the cave-products, will be described by Mr. Dana in a following part of this volume. I briefly mention here a few of the facts that have a special bearing on metamorphism.

1. The minute crystals in the cavities of the ejected masses, instead of being zeolites, such as exposure to the weather might have produced, have been proved by Mr. Dana, as has been stated to be identical with the anhydrous constituents of the lava. Minute transparent acicular crystals have given him the angles of pyroxene; white rhombic tables, the characters of a triclinic feldspar, so that they are probably labradorite; and besides, there are brilliant iron black octahedrons of magnetite and tables of hematite or titanic iron. These are all the constituents of the basalt except the less constant one, chrysolite.

2. The caves and tunnels of Kilauea and of the Mt. Loa lava-stream of 1880–81, afford stony stalactites, remarkable for their slender pipe-stem like size and form, scarcely tapering at all except at the extremity, where there is usually a short irregular twist. The diameter is hardly a fourth of an inch. In 1840 I found only short specimens in the caves of Kilauea: but in 1887 in the tunnel of the lava of 1880–81, near Hilo, many were 20 to 30 inches long; and in some undisturbed parts of the tunnel there were thickets of these, long gray-black stalactites, one every six or eight inches. Over the floor beneath each, there is a column of stalagmite of similar nature, which is a heap of bent coalescing drops or anastomosing stems from a few inches to fifteen or more in height. Most of the stalactites were solid, with occasional cavities, but many were tubular. Mr. Brigham observed them in the Kilauea caves in 1864–5, and has good figures on page 463 of his Memoir.

These stony stalactites appeared, under a pocket lens, to be identical with the rock of the lava-stream, even to the laths of labradorite, and the cavities showed minute transparent acicu-

lar and tabular crystals, besides black octahedrons of magnetite. The microscopic investigation of Mr. Dana proves that they actually are like the lavas in constitution, and that the crystals are of pyroxene and feldspar as in the ejected blocks.

The origin of the stalactites of the tunnels and their crystallizations is due, as I state in my Expedition Report (p. 201), to "the action of steam on the roof of the cavern." In the case of the tunnels the flowing lavas left behind a chamber filled with superheated steam, and under its action the solution and recrystallization went forward.

This reproduction of the basalt and the making of the crystals in geodes, or as linings of fissures, are examples of metamorphic work. It is metamorphism of the *crystallinic* kind*, the same which takes place when a feldspathic sandstone is converted into granite or granulyte, or when calcyte is changed into marble; and it is therefore one of the common kinds of metamorphism.

4. The ejected blocks about Kilauea instruct us on another point of much geological importance. They show that the throat of a volcano is necessarily a region of metamorphic action. It is a region of continued heat; and heat always works change when moisture is present. Under such conditions, therefore, an Archæan limestone or other Archæan rock containing chondrodite, spinel, vesuvianite, scapolite, anorthite, nephelite, biotite, might lead to the production of recrystallized chondrodite (humite), spinel, vesuvianite, scapolite (meionite), anorthite, nephelite, biotite (or meroxene) as metamorphic results; and in just the situation where an explosive eruption might detach masses and bring them up to the light. It is noteworthy that the above minerals of the ejected blocks about Somma, which have long been regarded as throat minerals of Vesuvius, crystallized by the volcanic heat as held by Scacchi, are kinds that are characteristic of Archæan rocks and especially of an Archæan limestone, rocks which may underlie the later limestones and other strata. There is little assumption therefore in saying that some of these crystallizations illustrate specifically crystallinic metamorphism, though others may be of the metachemic kind, that is, products of chemical change.

From the side of a fissure near the bottom of the emptied basin of the lava-lake called the "Old Beggar," was taken, at my visit in August, 1887, a specimen as large as the hand, covered with minute white tabular crystals, with some transparent crystals of acicular form. The mineral turned out to be gypsum, common as an incrustation in Kilauea caves.

* "On terms applied to metamorphism," this Journal, III, xxxii, 70, 1886.

III. The form of Mt. Loa a consequence of its Eruptions.

Mt. Loa differs from almost all other volcanic mountains in having a double curvature in its profile, owing to the flattening and widening of its summit, and the spreading of its base. It is the flattened summit which gives so vast bulk to a mountain of its altitude.

This peculiarity I attributed in my Expedition Report, to the positions of the prevailing outflows, on the ground that discharges of lavas about the base tend to widen and flatten the base and give a single concavity to the profile on either side; that discharges at the summit, especially if in short streams, serve to elevate the summit and make still more pronounced the single concavity; but that discharges over the upper slopes and not over the summit, tend to widen the upper part and flatten the summit so as to produce a convexity in the profile above.

The outflows of the century have had the distribution required to produce the actual form. Part are basal; another large part start just below the summit, and none of much size from the vicinity of the summit crater. The double curvature so produced, however, is mostly confined to the eastward and south-southwestward slopes, the chief directions of expansion by basal outflows; moreover, the widening in the former direction owes much, beyond doubt, to the eruptions of Kilauea. Further: *owing to the absence nearly of cinder-ejections*, the summit fails of the most common means of growth in height with tapering top; and this is a prominent source of the difference between it and most other volcanic mountains.

Another cause tending to modify the shape of the mountain is that producing fractures and subsidences. Its effects are seen about the great craters, and still more pronounced about the borders of the island. The former action aids in making summits broad and flat, while the latter works directly against the widening of the coast region. It makes the greatest fractures, nearly parallel with the coast and drops the coastward block; it thus tends to shorten the radius of that part of the mountain and put precipices into its profiles, increasing thereby the mean slope. Two such walls in southern Hawaii, cross the road between Keauhou and Kilauea, one about a mile and a half from the coast and the other three miles; they are marked features before the traveler in his ride from the coast to the volcano. These faultings seem to be a reason for the concavity in the southern coast-line from Keauhou westward, and for the short distance in that direction between the summit and the coast. Other great fault-planes exist; but the government map of the island should be completed before the facts can be satisfactorily discussed.

Sagging from pressure and consequent crushing has been made a cause of a single concavity between the top and the base of a volcanic mountain, and mathematical calculation has found a conformity between physical law and the shapes of such mountains in Japan and America. But there can be no crushing from gravitational pressure in a mountain made almost solely of lava; and it is hardly a possible result in any existing cone if made up even one-half of lava-streams, braced as they are by dikes.

The following are the mean slopes of Mt. Loa from the summit along different radii. The distances made the basis of the calculations are taken from the Government map:

S.S.W. to the southern cape	$1 : 13{\cdot}1 = 4^\circ\ 22'$
S.E. by S. to the indented Kapapala shore	$1 : 9 = 6^\circ\ 20'$
S.E. to foot of slope W. of Kilauea	$1 : 9{\cdot}12 = 6^\circ\ 15'$
E.N.E. to shore at Hilo	$1 : 14{\cdot}86 = 3^\circ\ 51'$
W. by S. to western shore	$1 : 8{\cdot}11 = 6^\circ\ 43'$
N. by E. to plain between Loa and Kea	$1 : 9$ to $1 : 10 = 5^\circ\ 50'$ to 6°

In a circle of five miles around the summit crater the mean slope is about 3°: the mean depression to the eastward at the perimeter of the circle is about 1400 feet.

From Kilauea to the eastern cape, 28 miles, the slope is $1 : 36\frac{1}{3} = 1^\circ\ 35'$.

The fact that Mt Loa as well as Kilauea were made over a great fissure has given an oblong and approximately elliptical or ovoidal form to all the upper contour lines of Mt. Loa. Further, the bend in the longer axis of the summit crater, making the concavity to the eastward, is also expressed, according to the large government map, in the form of the upper part of the dome.

At what period in its history, Mt. Loa left off superfluent discharges and took to having only the *effluent*, or those through fissures, it is impossible to say. But as the walls both of Kilauea and the summit crater are made up of the edges of lava-streams to the very top, it would appear that summit overflows from the crater may have continued in each to a comparatively recent time. It is remarkable that the north and west walls of Kilauea, which show well the stratification from top to bottom, have almost no intersecting dikes.

In the following paper, the relations of the Kilauea volcano to Mt. Loa will be considered, and the question as to the effects of volcanoes on the depths of the ocean.

[To be continued.]

Art. XII. — *The Fayette County, Texas, Meteorite;* by J. E. Whitfield and G. P. Merrill.*

The meteorite described below was found some ten years ago at Bluff, a settlement on the Colorado River about three miles southwest of the town of LaGrange, in Fayette county, Texas. Bluff cannot boast of being a village as it is simply made up of a few farms scattered within a radius of two miles. The farmers are mostly Germans or Bohemians, and as they are generally of the superstitious class, it is not strange that the finder, a Bohemian, named Raniosek, should have been struck by the appearance of the stone, and especially by its weight. As it is probable that he never heard of such a thing as a meteorite it is safe to say that he did not know the nature of his find; still he seems to have come to the conclusion that it was something foreign to the soil.

There is a tradition in Fayette County that Santa Anna, at the time of his flight after the battle of San Jacinto, buried his war-treasures somewhere near LaGrange, and the belief has so fixed itself in the minds of the inhabitants that many fruitless attempts have been made to discover it. The finder of the meteorite, with the tradition fresh in his mind, reasoned that so large and heavy a stone must mark the place where some treasure was deposited; he therefore rolled the stone a few feet aside and dug a deep hole at the exact spot where the stone had been, without finding anything to pay him for his labor.

For several years the stone lay where the Bohemian had left it; then he sold the piece of land to Mr. C. Hensel, who still owns it; but before the latter had taken possession, Raniosek removed the stone to his own farm, about a mile away, where for five years more it lay neglected in his yard. His reason for removing it was that its weight led him to suspect it contained some valuable metal.

About three years ago Mr. H. Hensoldt took charge of the school at Cedar, two and one-half miles from Bluff settlement. By spending his spare time in hunting over the ground for fossils, minerals, etc., the attention of the farmers was drawn to him, and in January, 1888, he was informed of the strange stone in Mr. Raniosek's yard. Immediately on seeing it he recognized it as a meteorite, and a very fine specimen of its kind.

After obtaining possession of the stone Mr. Hensoldt disposed of it to Messrs. Ward and Howell, of Rochester, N. Y.,

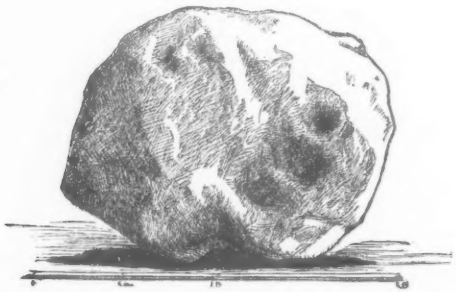
* The chemical work was done in the laboratory of the U. S. Geological Survey; the petrographical work in the laboratory of the U. S. National Museum.

to whom we are indebted for the material for study and the privilege of description. On receiving the stone, Mr. Howell published a notice in Science (Feb. 3, 1888, p. 55) putting it on record as the "LaGrange Meteorite," but on finding that this name had already been applied to the Oldham County, Kentucky, meteorite, agreed that it should be called the Fayette County Meteorite.

The stone possesses all the characteristics of a meteorite. The pittings are well marked, but the crust shows only in the deeper depressions; a freshly fractured surface shows, besides the grains of metal, a greenish gray appearance not unlike some greenstones. A particularly interesting feature of the stone is the presence of a few dark-colored veins varying greatly in dimensions—the one in the specimen for examination being some 2^{mm} in greatest width, and 60^{mm} in length.

The three dimensions of the mass are $58^{cm} \times 46^{cm} \times 28^{cm}$, and the total weight about 146 kilos. A good idea of the appearance of the meteorite may be had from figure 1.

1.



Before the specimen was pulverized for analysis the vein was carefully sawed out so as to keep all the vein material from the mass. The rock was then ground as fine as possible, and a portion (1 gr.) treated with iodine in cold water, to separate the metallic particles. The residue was filtered on a Gooch soluble filter and washed free of iodine. The rocky material after being weighed was treated with dilute hydrochloric acid and allowed to stand for some time, then filtered and the residue weighed. In both cases the mineral being separated from the filter by using the proper solvent for the anthracene—washed with ether and alcohol and dried at 100° C. This temperature not being sufficient to drive all the water from the mineral part accounts for the discrepancy of about 2 per cent.

The following figures will show the composition of the metal and the rock, soluble and insoluble, in hydrochloric acid; also the results of a complete analysis of the total mass:

	No. 1. Total mass.	2. 5·67 per cent total. Metal.	3. 33·3 per cent of total. Insol. in HCl.	4. 60·62 per cent total. Sol. in HCl.
SiO_2	= 37·70		49·64	33·59
Fe	3·47	82·42	----	----
FeO	23·82		15·56	31·12
Al_2O_3	2·17		4·12	1·34
P_2O_5	·25			·42
CaO	2·20		4·93	1·00
MnO	·45		·54	·43
MgO	25·94		25·21	28·08
NiO	1·59		trace.	2·66
Ni	·65	15·44	"	
CoO	·16		"	·27
Co	·09	2·14		
S	1·30			2·18
	99·79	100·00	100·00	101·09
Less O, for S,	= ·65			= 1·09
	99·14			100·00

Sp. gr. = 3·510.

The percentages in all except the first are calculated from the weight found.

From these figures it will be seen that the minerals which go to make up the rocky portion of the meteorite are essentially olivine and enstatite, with considerable pyrrhotite, as is also shown by the microscopical description.

The stone belongs to the class of meteorites to which G. Rose* has given the name "chondrites." To the unaided eye the chondritic structure is not distinctly marked, a broken surface showing a fine grained and evidently crystalline-granular rock, very compact, of a greenish gray color and thickly studded with small metallic points with a brassy luster. A polished surface shows the stone to be composed of small chondri rarely over 2^{mm} in diameter, thickly and firmly compacted in a fine granular groundmass. Throughout the entire mass are thickly distributed innumerable small irregular flecks of a steel-gray, brassy and bronze-yellow color, presumably native iron and pyrrhotite.

The striking feature of the stone is its fine and compact texture, which exceeds that of any chondritic meteorite with which we are acquainted, but which is perhaps most closely approached by the stones of Dhurmsala, India, and Cabarrus county, N. C.

Thin sections of the stone show, under the microscope, a confused aggregate of rounded and irregular, often fragmental olivine and enstatite grains and chondri, imbedded in a fine granular groundmass of the same mineral composition.

The chondri occur in both monosomatic and polysomatic forms composed either of olivine or enstatite alone or the two

* Abhandl. der Königl. Akad. d. Wissensch. zu Berlin, 1863, p. 161.

minerals associated. The peculiar grate-like or barred forms so characteristic of olivine chondri are here represented, as are the radiating fan-shaped forms of enstatite.

The large greenish microscopic chondri are, under the microscope, seen to be made up of innumerable enstatite granules so arranged as to form oval or fan-shaped areas of radiating columns enclosing large, quite perfectly outlined crystals of the same mineral. These included forms are nearly colorless or merely gray through enclosures of innumerable dust-like particles, and show sharp and well defined cleavages parallel to either prism, and a parting parallel to the orthopinacoid. Both olivine and enstatite are nearly colorless or gray through enclosures of dust-like particles, and carry but few cavities.

In addition to the minerals above mentioned there were noticed occasional broad, irregular plates of a monoclinic mineral, light gray in color but polarizing brilliantly in red and yellow colors and which gave extinction angles varying from 25° to 31°. Such are presumably augite or a closely allied pyroxene. Nothing that can be certainly identified as a feldspar was observed. Occasional small, nearly colorless, angular forms show faint indications of twin structure, and it is possible may be a plagioclase. In two sections were observed irregular outlined interstitial areas, perfectly colorless and full of gas cavities. These in some cases remained quite dark during a complete revolution of the stage, and in others gave decided polarization in light and dark colors, and in converging light showed indistinct biaxial interference figures. The position of these areas relative to the other constituents is that of an interstitial glass or a secondary mineral, like a zeolite. As they show neither cleavage nor crystallographic outlines, and moreover are to be found but rarely in the sections at hand, it is impossible to identify them satisfactorily.

2.

Natural size.

The metallic iron occurs in the usual rounded and irregular masses one to two millimeters in diameter and is apparently in about equal proportions with the pyrrhotite: the latter showing a bright brassy luster in strong contrast with the silvery white iron.

The black vein above noted traverses the stone in the form of an irregular fissure (often expanding and contracting abruptly as is shown in figure 2), for a distance of about 60^{mm}, and varies in width from a mere line up to 2^{mm}. Near its lower end it bifurcates and encloses a portion of the mass of the meteorite some 15^{mm} long by 2^{mm} wide.* From a fragment

* Since the above was written Messrs. Ward and Howell have sliced the stone through the center and published in Science of June 1, 1888, a figure showing the full extent and width of the veins.

containing a portion of the vein thin sections were prepared, and the remaining vein material, separated as clearly as possible from the enclosing rock, was subjected to chemical analysis, the process being essentially the same as in the analysis of the meteorite proper. Although the vein material is more compact and much darker in color, the analysis shows very little difference from that of the mass, the main apparent difference being the absence of the lime-bearing mineral. The following are the figures obtained by analysis on material that weighed a little less than 0·4 grams:

Metal.		44 per cent of vein. Insoluble in HCl.		51 per cent of vein. Soluble in HCl.
Fe	= 2·30	SiO_2	= 56·52	27·63
Ni, Co	trace	FeO	12·35	34·31
		Al_2O_3	1·51	2·41
		CaO	trace	trace
		MgO	25·53	32·12
		(NiCo) O	4·09	3·27
		S	----	·52
			100·00	100 26
			Less O, for S =	·26
				100·00

Sp. gr. = 3·585.

The same difficulty, with regard to water in the mineral, exists here as in the analysis of the mass.

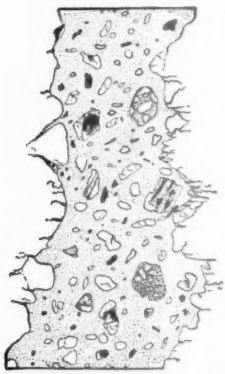
From the figures it appears that the portion soluble in hydrochloric acid is essentially olivine in composition, while the insoluble is evidently a mixture of the same insoluble constituents as the mass of the meteorite. The filling material of the vein is, to the unaided eye, quite black and without luster; under the microscope it is seen to penetrate very irregularly and by innumerable minute vein-like ramifications into the stony mass on either side and to carry numerous enclosures of a colorless mineral substance and blebs of metallic iron and pyrrhotite. The exact nature of the colorless enclosures cannot be ascertained. On treating an uncovered slide with hydrochloric acid a part of these were dissolved, others were unacted upon. Under the microscope they are full of irregular rifts and fracture lines but show no true cleavages. Some of them are in the form of single individuals, others have the structure of fragments of polysomatic chondri. Nearly all contain included black amorphous material and many show distinctly included specks, giving the silvery white and brassy yellow reflections of the metallic iron and pyrrhotite. In many cases they are not separated from the black vein material by sharp lines but seem to pass into it by gradations. Between crossed nicols many of them act like a gum, others remain always light, recalling the well known crypto-crystalline

structure of chalcedony and still show, here and there, occasional small areas giving the characteristic polarization colors of olivine and enstatite. On examining the walls of the vein, areas were observed where the gray and yellowish enstatites and olivines retained their normal properties at the distance of one or two millimeters, but at contact with the black vein matter were reduced to the colorless non-polarizing condition of the enclosures.

The black matter of the vein when viewed in strong reflected light shows a dull bronze luster, less brilliant than that of the pyrrhotite particles which it encloses. The thinnest portions of the slide when examined with a power of 175 diameters show a brownish amorphous base through which are scattered abundant irregular dust-like particles and flecks of a perfectly black opaque material, the nature of which it is impossible to ascertain by the microscope alone.

The structure of the vein is shown in figure 3 in which the finely dotted portions represent the black amorphous vein matter with bronzy luster, the entirely black area, the blebs of metal and pyrrhotite, and the irregularly rounded, clear or partly clouded area, the colorless silicates.

3.



Portion of vein highly magnified.

From the study of these veins as above described, we are inclined to consider the colorless particles as olivine and enstatite residuals which have been deprived of their normal optical properties by the forces active in forming the vein. What the exact character of the black and amorphous material may be, still remains a matter of conjecture. It is unacted upon by acids and when tested with a needle point it breaks up readily into earthy fragments which are not attracted by the magnet.

Mr. Howell informs us that the stone in his possession shows three of these veins, the largest exposure of any one on a broken surface being about four inches. The width and general character of all, he states, appears to be uniform throughout, though this can be ascertained definitely only by breaking the stone.*

* In structure these veins seem to only remotely resemble those described by Tschermak (Sitz. der Kais. Akad. der Wiss., lxxxv, 1, p. 204), in the Mocs meteorite and which, it will be remembered, he argued indicated an elevation of temperature since the consolidation of the stone, such as aided by reducing vapors and gases fused the iron and pyrrhotite without affecting the silicates. He describes the brown and black "Fullmasse" of the vein as an admixture of the same sub-

Owing to the small amount of vein material which was available for chemical analysis and the impossibility of separating it completely from the enclosing rock, the results obtained can be regarded only as suggestive. The main points brought out can be best shown by reproducing here a comparison of the results:

Mass of meteorite.		Vein material.
SiO_2	= 37·70	38·96
Fe	4·41	2·30
FeO	23·82	22.98
Al_2O_3	2·17	1·89
CaO	2·20	trace
MnO	·45	----
MgO	25·94	27·52
Ni Co	1·75	3·26
S	1·30	·26
Sp. gr. = 3·510		Sp. gr. = 3·585

These differences are too slight to be considered of great value until found to be constant by further investigation. It is to be hoped that the ultimate possessor of the stone will regard a knowledge of its true character as of first importance and will not hesitate to sacrifice any necessary amount for the purpose of an exhaustive examination by the most advanced methods. Our most sincere thanks are due Mr. Hensoldt for kindly furnishing us with the information regarding the discovery of the meteorite.

Washington, D. C., April 12th, 1888.

Art. XIII.—*Evidence of the Fossil Plants as to the Age of the Potomac Formation;** by Lester F. Ward.

It is remarkable that the geologic age of the formation upon which the cities of Baltimore, Washington, Fredericksburg and Richmond stand should have remained unknown to the present day. My contribution to this subject relates en-

stance as the meteorite itself, and an opaque, half glassy black admixture resembling the black vein-like material of the Orvinio stone. The silicates occur in the vein in the form of small sharp splinters, the iron in granules and the pyrrhotite in the form of little leaves and small kernels, often so arranged as to give rise to a fluidal structure. Dr. Hans Reusch has described (N. Jahrb. für Min., iv Beil. Band., 3d heft, 1886, pp. 491–2), veins in the Ställdalen meteorite which present features in part common to those of the Fayette stone. To the unaided eye the filling material is black and opaque and carries metallic particles. Under the microscope it shows a brownish gray, isotropic and sometimes opaque glassy substance densely crowded with rounded transparent fragments. The upper figure in his Plate XIV closely resembles in structure the vein matter of the Fayette stone, but as far as can be judged from his description the included particles seem to have retained their normal optical properties. Reusch regards this black vein material as the result of a partial refusion of the chondrite substance.

* Read before the National Academy of Sciences at Washington, April 20, 1888.

tirely to the evidence which the vegetable remains found in that formation furnish toward the solution of this question. Until quite recently this was the only paleontologic evidence attainable, but within the past six months vertebrate remains have been found which are of the highest value. Indeed, with the exception of a few ferns obtained by Mr. F. Shepherd near Fredericksburg, Virginia, and figured with very imperfect descriptions in a paper by Richard C. Taylor, published in the Transactions of the Geological Society of Pennsylvania, in 1835,* it is only within the past five or six years that the existence of plants, other than silicified wood and lignite, in this formation has been made known. For their discovery, thorough investigation, and careful elaboration, we are almost wholly indebted to Professor Wm. M. Fontaine, of the University of Virginia. Four years ago, Professor Fontaine brought to Washington some specimens collected at Fredericksburg in what he then regarded as Jurassic strata, which, though quite imperfect, he had observed to differ from all the ferns, conifers and cycads of true Jurassic type, and to resemble in many respects dicotyledonous leaves.

Although aware that certain ferns, such as Dictyophyllum, Thaumatopteris and Clathropteris, having decidedly net-veined fronds, have been found in Jurassic strata, nevertheless, so different were these leaves from such forms, and so similar were they to modern deciduous leaves, that I expressed at the time my conviction that they were true Dicotyledons, though of an archaic type; and speaking of them in my article on Mesozoic Dicotyledons, in this Journal for April, 1884, I said (p. 303) that they "certainly possess all the essential elements of Dicotyledonous leaves, although at the same time bearing a certain recognizable stamp of the cryptogamic and gymnospermous vegetation that characterizes that earlier age."

As the subclass Dicotyledons, formerly called angiospermous Exogens, had at that time, with the exception of a single somewhat doubtful species, never been found lower than the Cenomanian of France, Quadersandstein of Germany, Middle Creteceous of Greenland, and the Dakota Group and Amboy clays of the United States, all of which are usually regarded as nearly equivalent in age and as representing the middle member of the Cretaceous above the Gault, my interest in this apparently great downward extension of this class of plants was from the first of the liveliest character, and I have from that day not only watched eagerly the progress of Professor Fontaine's investigations, but have accompanied him on several of his collecting tours through the States of Virginia, Maryland and North Carolina, and have carefully studied the beds hold-

* Vol. i, pp. 320–325, Pl. XIX.

ing the plants, the character of the specimens in place, and the general nature and affinities of the flora of the Potomac formation.

In the course of this investigation the accuracy of my conjecture as to the true nature of the forms I have mentioned has been abundantly verified, and we have now, described and figured by Professor Fontaine, no less than seventy-five species of undoubted Dicotyledons in this flora. These forms, together with a number of others to which I shall presently refer, have led Professor Fontaine to change his mind slightly as to the age of this formation, and instead of Jurassic, as first believed by Rogers, he now, as I understand, inclines to adopt the later view of that authority that they are Jurasso-Cretaceous and will prove to form a group of passage beds between the Jurassic and Cretaceous, similar to the Wealden of Europe. Professor Fontaine, however, prefers to call the flora Neocomian, which he gives a wide range as including all the older Cretaceous from the Gault downward, and of which he regards the Wealden as an equivalent fresh-water deposit.

My object in the present paper is simply to show, in as clear and direct a manner as possible, what the fossil plants of the Potomac formation indicate as to its age, and I shall not advocate any special view of the case.

With the exception of five species described by Professor F. H. Knowlton from a study of the internal structures of the silicified wood and lignite, in a paper soon to be published,* it is to Professor Fontaine that we are exclusively indebted for the details which I have summarized in the present paper. At the expense of vast labor he has studied, described and delineated the extensive collections made almost entirely by himself, and has prepared an elaborate manuscript, with 174 plates, which has not yet been published. He has very kindly placed this unpublished work at my disposal, and it is from it that I have chiefly compiled the data which I have to present. Without such a compilation it would be impossible to determine the precise relations of this flora to those of other formations. Professor Fontaine seems not to have undertaken such a compilation, and must have depended for his opinion of the age to which the flora points upon the impression made on his mind by each species separately and that produced in his memory by the *tout ensemble*. Considering this, it is certainly remarkable how accurate his judgment was, and I am not prepared to affirm that the conclusions which flow mathematically from the statistical view here presented, taken in themselves, differ in any marked respect from Professor Fontaine's intuitions.

* Bulletin U. S. Geological Survey, No. 53.

Elements of the Potomac Flora.

	Equiseta.	Ferns.	Cycads.	Conifers.	Dicotyledons.	Uncertain.	Total.
Number of Genera	1	19	11	19	29	1	80
" New Genera		3	2	7	19		31
" Species	3	139	28	112	76	12	370
" New Species	2	133	26	105	76	12	354
Species founded on leaves, fruits, etc.	3	139	28	107	76	12	365
" " internal structure				5			5
" occurring elsewhere (identical)	1	6	2	7			16
" allied to previously known species	1	45	8	26	17	1	98
" admitting of comparison	2	51	10	33	17	1	114
" not admitting of comparison	1	88	18	79	59	11	256

I have prepared the foregoing table, showing the principal elements of the Potomac Flora as elaborated by Professor Fontaine and Professor Knowlton, from which it appears that the whole number of species thus far known is 370, consisting of 3 species of Equisetum, 139 ferns, 28 cycads, 112 conifers, 76 dicotyledons, and 12 species whose systematic position is not definitely known. Of this number, 354 are new species, leaving only 16 species which are common to the Potomac and other formations. But in comparing these new species with the other fossil floras of the globe, 98 of them have been found to resemble to a greater or less extent species figured from elsewhere, leaving 256 species, or nearly 69 per cent, which do not sufficiently resemble known forms to suggest any close relationship. It is therefore only the 16 identical and 98 presumably allied species, or considerably less than one-third of the whole flora, that we have to do with in our comparison of species. The forms with which these 114 species are found to possess characters in common are derived from 37 distinct floras, ranging from the summit of the Trias to the base of the Tertiary, but chiefly within Jurassic and Cretaceous strata.

Rhetic.—The formation called Rhetic, which some regard as the base of the Jura and others as uppermost Trias, is the oldest that has yielded forms which are comparable with any found in the Potomac formation. Such forms are found at three, and if we include certain beds in China, at four different localities widely separated from one another, which have been correlated as of Rhetic age. The most interesting of these is that of the Richmond Coal Field in Virginia which Professor Fontaine has himself elaborated, and in which he believes he finds the ancestral types of some half dozen Potomac species,

in four of which the resemblance is close enough to warrant the preservation of the generic name.

A somewhat larger number of species are compared with those of Franconia and Seinstedt in Germany, though here the affinities are less close. Six species are compared with forms from the well known Rhetic beds of Sweden and three with the Jurassic of China where Dr. Newberry found plants identical with those collected by Emmons in North Carolina.

Taking all these Rhetic localities together we find that fourteen Potomac species have important characters in common with Rhetic plants, although none of them are specifically identical.

Lias.—The Rajmahal group of India has generally been referred to the Lias and is the only flora of that age which contains types that reappear in the Potomac beds. Six species are compared in three of which the same genera occur, but two of the remainder either present only an accidental resemblance or there has been a mistake in their generic reference.

Oolite.—Six Oolite beds contain analogous forms to those of the Potomac These are: 1. The Upper Gondwanas of India; 2. That of Cape Boheman, Spitzbergen; 3. Those of eastern Siberia; 4. Those in Russia, worked up by Schmalhausen; 5. Those of Italy monographed by Zigno; and 6, the celebrated Yorkshire Oolites. The Siberian and Yorkshire beds, however, have yielded the greater part of the species allied to Potomac plants. Thirty-one species of Potomac plants have allies in the Oolite flora, but as yet there occur none that are identical.

Upper Jura.—The upper Jurassic deposit at Solenhofen in Bavaria, the Coral beds of Verdun and St. Mihiel in France, and the Kimmeridge strata at Morestel and the Lac d'Armaille, have each yielded forms, especially of the coniferous genus Brachyphyllum, which closely resemble Potomac specimens.

Wealden.—The Wealden of England furnishes two species which also occur in the Potomac formation. These are *Equisetum Lyelli* Mant., and *Sphenopteris Mantelli* Brongn., the latter of which also occurs in the Wealden beds of Germany, first monographed by Dunker. Besides these there occur on the Island of Portland and the Isle of Wight certain Cycadean trunks referred to Cycadeoidea, Bennettites and Mantellia, which are very similar to those found by Tyson in Maryland, called by Professor Fontaine *Tysonia Marylandica.*

A much larger number of identical species are found in the Wealden of Germany. Besides the one already mentioned as common to strata of that age in England and Germany, we have *Pecopteris Browniana* Dunk., *P. Dunkeri* Schimp., *Dioönites Buchianus* Schimp., *Dioönites abietinus* Miquel,

Sphenolepidium Kurrianum Heer, and *S. Sternbergianum* (Dunk.) Heer, in all seven identical species. Nine other Potomac species have allies in the Wealden of Germany.

Four Potomac species are allied to plants found in Japan, in deposits usually regarded as Jurassic, but which may be lower Cretaceous.

Forms of *Pecopteris Whitbiensis* found by Trautschold at Klin near Moscow closely resemble *Cladophlebis falcata* and *C. oblongifolia* of the Potomac flora. Professor Fontaine, following Schenk, regards this deposit as Wealden.

Neocomian.—The principal beds recognized as belonging to this series containing Potomac types, are those of the Valle de Lobos and of Almargem in Portugal, whose flora was elaborated by Heer in 1881. Four of the Wealden species found in the Potomac and already enumerated recur here, leading to the strong suspicion that the Portuguese beds may also be of Wealden age. One of these (*Sphenolepidium Sternbergianum*) is also found in alleged Neocomian strata near Oerlinghausen in Westphalia.

Professor Fontaine's *Taxodium Virginicum* appears to be allied to *T.* (*Glyptostrobus*) *Groenlandicum* of Heer, which occurs in the Kootanie beds of the British Northwest Territory, correlated by the Canadian geologists with the Neocomian, and *Araucarites Virginicus* resembles *Araucaria cretacea* Brongn. from Nogent-le-Rotrou in France, which is thought to be not lower than Cretaceous.

There are therefore four species common to Neocomian and Potomac strata, and seven others which are related more or less closely.

Urgonian.—To this epoch are referred the Kome beds of Greenland, and the Wernsdorf beds, lying chiefly in Austrian Silesia. The rich flora of the former was elaborated by Heer, and it will be remembered that it was here that a single dicotyledonous plant, *Populus primaeva* Heer, was found which, if no mistake was made, was the most ancient plant belonging to that subclass that had been found prior to the opening up of the Fredericksburg beds. This species does not occur in the Potomac flora, but five other Kome species do occur there, viz: *Gleichenia Nordenskiöldi* Heer. (though this is somewhat doubtful), *Sequoia Reichenbachi* (Gein.) Heer, *S. ambigua* Heer, *S. rigida* Heer, and *S. gracilis* Heer. Besides these identical species there are eleven Potomac plants that bear more or less resemblance to those of Kome.

The Wernsdorf beds contain two species found in Potomac strata, one of which, *Dioönites Buchianus* Schimper, does not occur at Kome, and there are four other species of Potomac

plants that have near relatives in that deposit. The Urgonian therefore furnishes six identical and sixteen allied species.

Gault.—The Cretaceous deposit at Cape Staratschin, in Spitzbergen, which has been referred to the Gault, contains two of the species that have been enumerated as occurring in the Kome beds and also in the Potomac formation, and also two other species which resemble Potomac plants.

Cenomanian.—The rich Cretaceous flora of Atane, Greenland, so carefully worked up by Heer and correlated with the Cenomanian of Europe, furnishes six species which have been detected in Potomac strata, but all but three of these, *Pecopteris socialis* Heer, *Aspidium Oerstedi* Heer, and *Sequoia ambigua* Heer, have already been enumerated from the Kome beds through which they extend up into those of Atane. The number of additional species with which there are related Potomac forms amounts to nine, but the relationships are in some cases quite distant.

The Cenomanian of Bohemia and Moravia has 1 identical and 6 allied species, and that of Saxony (Niederschöna) 2 identical and 3 allied, but one of the identical species is the same in both and has a wide range, while the other also occurs in the Wernsdorf beds.

We thus have for the Cenomanian 7 identical and 23 allied species.

Dakota Group.—In the Dakota Group, which should probably also have been classed as Cenomanian, only two plants occur which are also found in the Potomac formation, and both of these are found in other localities, one of them having a very wide range and distribution. The Potomac Dicotyledons are all specifically, and nearly all generically, distinct from those of the Dakota Group, but ten species are compared and may be related to Dakota forms.

Senonian.—Under this designation I have grouped the upper Cretaceous beds of Patoot, Greenland, of the Peace and Pine River district of the British Northwest Territory, of Quedlinburg in the Harz, the Gosau beds of Tyrol, the Westphalian beds, so well worked by Hosius and Von der Marck, and the sands of Aix-la-Chapelle. The same species recur largely in these beds, *Sequoia Reichenbachi* being found in them all. Five species are common to the Potomac formation and one or more to these localities, but all of these are found in older strata. Nine Potomac plants are also compared and perhaps related to Senonian species.

Laramie Group.—Only one species, the widespread *Sequoia Reichenbachi*, is common to the Potomac formation and Laramie group, and no further comparisons are made.

Eocene.—The two comparisons made with Eocene plants, viz: *Araucaria podocarpoides* with *Podocarpus incerta* Ett.

and Gard., and *Rogersia longifolia* with *Glossochlamys transmutans* Ett. and Gard., from the London clays, are too remote to possess any value for the present discussion.

The relations of the Potomac flora to those of other formations may now be summed up in tabular form. The 16 identical and 98 allied species are composed of 53 cryptogams, all but 2 of which are ferns, 9 cycads, 35 conifers, and 17 dicotyledons, and as the lower types are somewhat more prominently represented in the lower formations and the higher in the higher, this relation may perhaps be best shown in the following form.

Geological Formations.	Cryptogams.		Cycads.		Conifers.		Dicotyledons.		Total.	
	Identical.	Allied.	Identical.	Allied.	Identical.	Allied.	Identical	Allied.	Identical.	Allied.
Eocene						1		1		2
Laramie Group					1				1	
Senonian					5	7		2	5	9
Dakota Group	1				1	1		10	2	11
Cenomanian	2	9	1	1	4	5		8	7	23
Gault		1			2	1			2	2
Urgonian	1	7	1	2	4	7			6	16
Neocomian	2	2		1	2	4			4	7
Wealden	4	11	2	1	2	1			8	13
Kimmeridgian		1				3				4
Corallian		1				5				6
Oolite		24		2		5				31
Lias		4		2						6
Rhetic		8		4		2				14

From this exhibit it appears that no Jurassic species occurs in the Potomac formation, although it contains a large number of strongly Jurassic types. The Wealden furnishes the largest number of identical species, the Cenomanian next, and the Urgonian next. Of allied species, although the largest number occurs in the Oolite, the Cenomanian, Urgonian and Wealden, each furnish many. Taking the identical species and considering the Wealden as Cretaceous, the flora would appear to be decidedly Cretaceous, but if this showing is considered in the light the Jurassic types cast upon it, it is difficult to believe it to be higher than Wealden or Neocomian.

Another class of facts still further strengthen this view. Leaving the allied species aside, and considering only the identical ones, we see that a large number of these recur in most of the members of the Cretaceous. As already stated, there are only 16 identical species, while the sum of those in all the formations as here presented would be 35. This results from their repetition. Three species are confined to the Wealdne,

viz: *Equisetum Lyelli* Mant., *Pecopteris Browniana* Dunk., and *Dioönites abietinus* Miquel, which Prof. Fontaine treats as a variety of *Dioönites Buchianus* Schimp. Only one species is confined to the Urgonian, viz: *Sequoia gracilis* Heer, and only two to the Cenomanian, viz: *Pecopteris socialis* Heer and *Aspidium Oerstedi* Heer, both from the Atane beds of Greenland. The remaining ten identical species range through more than one series, most of them through several. Two species are found in the Wealden and Neocomian, viz: *Sphenopteris Mantelli* Brongn., and *Pecopteris Dunkeri* Schimp, which Prof. Fontaine regards as a true Aspidium. One Wealden species, *Dioönites Buchianus* Schimp, is found in both the Urgonian and the Cenomanian, and two, *Sphenolepidium Kurrianum* Heer, and *S. Sternbergianum* (Dunk.) Heer, are found in the Wealden, Neocomian and Senonian. One species, *Gleichenia Nordenskiöldi* Heer, occurs only in the Urgonian and the Dakota Group; another, *Sequoia ambigua* Heer, only in the Urgonian and Cenomanian of Greenland. *Sequoia rigida* Heer, occurs in the Urgonian, Gault, Cenomanian and Senonian, while *Sequoia Reichenbachi* (Gein.) Heer, runs through the Urgonian, Gault, Cenomanian, Dakota Group, Senonian, and is even found in the Laramie Group. The only species not already mentioned is *Sequoia subulata* Heer, which is found only in the Cenomanian and Senonian of Greenland.

These results can be shown in tabular form, and, if the species be arranged in ascending geological order they will stand as follows:

Species common to the Potomac and other Formations.	Wealden.	Neocomian.	Urgonian.	Gault.	Cenomanian.	Dakota Group.	Senonian.	Laramie.
Equisetum Lyelli *Mant.*	1							
Pecopteris Browniana *Dunk.*	1							
Dioonites abietinus *Miquel.*	1							
Sphenopteris Mantelli *Brongn.*	1	1						
Pecopteris Dunkeri *Schimp.*	1	1						
Sphenolepidium Kurrianum *Heer.*	1	1					1	
Sphenolepidium Sternbergianum (Dunk.) *Hr.*	1	1					1	
Dioönites Buchianus *Schimp.*	1		1		1			
Sequoia gracilis *Heer.*			1					
Sequoia ambigua *Heer.*			1		1			
Sequoia rigida *Heer.*			1	1	1		1	
Sequoia Reichenbachi (Gein.) *Heer.*			1	1	1	1	1	1
Gleichenia Nordenskioldi *Heer.*			1			1		
Pecopteris socialis *Heer.*					1			
Aspidium Oerstedi *Heer.*					1			
Sequoia subulata *Heer.*					1		1	

This presentation brings out in a clear light the value of these species in determining the age of the Potomac formation. Just half of them are found in the Wealden, and all but three occur below the Cenomanian.

Two problems of considerable importance remain to be considered, viz: First, how much weight to give to the large number of Jurassic types as indicating a Jurassic age for the formation, and secondly, how much to give to the Dicotyledons as pointing to a middle Cretaceous age.

As regards the first, we find that eight ferns, four cycads, and two conifers have representatives in the Rhetic, which some regard as uppermost Trias; four ferns and two cycads in the Trias, or lower Jura; 24 ferns, two cycads and five conifers in the Oolite, and two ferns and eight conifers in the upper Jura (Corallian and Kimmeridgian). These species, of course, overlap and recur in the different members in the same way as the identical species were shown to do, but nevertheless they present a strong case. For example, 27 out of 46 cryptogams, 4 out of 7 cycads, and 11 out of 28 conifers have allies in the Jurassic; that is, over half of the species, exclusive of Dicotyledons, that admit of any comparison at all, show affinities with Jurassic and Rhetic forms. And even this does not show the full force of the evidence of this class, since there are many genera, both of ferns and conifers, which predominate in the Oolite and in the Rhetic, and are either wholly absent or very rare in the Cretaceous, which yet have numerous representatives in the Potomac, and therefore all the species of these genera, whether they have closely related species in the Potomac or not, bear directly upon this point.

Thus Cladophlebis is represented by 22 species, only 14 of which are related to forms found elsewhere. The genus is chiefly Jurassic.

Thinnfeldia is a large Jurassic genus ranging from the middle Trias, but found also in the Cretaceous of Spitzbergen and Greenland. The Potomac species are, however, Rhetic in type.

Angiopteridium has no Cretaceous forms, and although there are two alleged Miocene species, the nine Potomac forms are strong lower Jurassic and Rhetic types.

Thyrsopteris, leaving Stur's Culm species out of the account, ranges from the Permian to the Malm of Portugal, held to be brackish-water Jurassic, called Wealden by Heer, but the genus is chiefly Oolitic. It is the most abundant fern in the Potomac formation, numbering forty species, only eight of which admit of specific comparison with forms previously known. Yet all of these forty species speak for the Jurassic age of the deposits containing them.

Platypterigium has been heretofore found only in the Lias of India. Its occurrence in the Potomac, therefore, in so far favors the same conclusion.

Brachyphyllum is a well known upper Jurassic type, but is found as low as the Muschelkalk and as high as the Neocomian. An occasional species in the Cretaceous would not be considered strange, but we find stems, leaves and fruits referable to five species in the Potomac formation, all of which are comparable to those found in the Corallian and Kimmeridgian deposits of France and of Solenhofen in Bavaria.

Other cases might be considered, but these will suffice to show how strong a Jurassic facies the Potomac flora possesses.

It remains to consider the second question, as to the true significance of the Dicotyledons. Their presence is supposed to indicate a later age than that denoted by the other groups of plants. It was long supposed that the upper Quader beds of Blankenburg contained the earliest remains of plants of this class, but they were at length found in the considerably older strata of Niederschöna in Saxony. Since then their occurrence in strata of about the same age in Bohemia and Moravia was made known, and it is the practice to treat the so-called upper Cretaceous of Greenland, the Dakota Group of Kansas and Nebraska, and the Raritan clays of New Jersey as homotaxially equivalent to these Continental deposits.

With but a single exception no dicotyledonous plants had been found lower than this horizon prior to the discovery of the Fredericksburg bed. This exception was the occurrence among the collections from Kome in Greenland, a deposit whose animal remains are said to fix its age as Urgonian, of a single dicotyledonous species, the *Populus primæva* of Heer, all the other plant remains from that deposit belonging to the lower types. Although this discovery has not been confirmed by subsequent research, and therefore remains subject to the doubt whether the collections may not have become mixed with those from higher beds made and sent at about the same time, still there is nothing antecedently improbable in it, and it may pass unquestioned. It does not, however, invalidate the general proposition that up to this time the Cenomanian has furnished the most ancient forms of dicotyledonous plants.

This cannot now be said, and we have in the Potomac formation a still earlier date at which to fix the observed origin of the type of vegetable life which is now the predominant one upon the globe. What then does this dicotyledonous element in the Potomac flora prove as to the age of that formation? Can we argue from its analogy with other Cretaceous floras? In doing so great caution is required. As compared with these the Potomac flora is wholly anomalous in this respect. In all the

others, with the sole exception already mentioned, instead of those plants coming in gradually, as they would be expected to do if the formation represented an age at which their development was inchoate, and instead of presenting rudimentary, transition, and archaic types of that subclass, as such early deposits would naturally do, we find them to be the prevailing, sometimes, as in the Dakota Group, almost the only form of plant life, and we also find them fully developed, and even when most unlike our modern vegetation, still exhibiting all the characters of highly organized plants of their rank. In the Potomac formation, on the contrary, we find the Dicotyledons behaving precisely as they ought to behave in a formation that represents an age close down to that at which this form of life first made its appearance in the geologic history of the globe. We find them to constitute the great rarities of the flora, absent from many of the most productive beds, scarce at all places in comparison with the lower types of vegetation, strange and peculiar in character, so vague and ill-defined as in some cases to cause doubts as to whether they really belong to this group of plants, possessing features that recall the ferns, Cycads, Conifers, and even the Monocotyledons, and containing comprehensive types prophetic of many of the now fully developed families of Dicotyledons. They therefore form just such a homogeneous and undifferentiated group of plants, combining in a scarcely distinguishable way all the elements of the later dicotyledonous flora, as we should expect to find existing during the early history of this type of vegetation. They are therefore not to be regarded as anomalous but as normal, and the anomaly, if any there be, exists in Cenomanian floras, where this type occurs in such a predominant and highly developed form.

In view of these facts I cannot accept the conclusion that the dicotyledonous element of the Potomac flora argues a more recent age than that denoted by the other types. On the contrary, the immense difference between this and the Cenomanian floras clearly indicates that a vast period must have been required to produce so great a development.

On numerous occasions, dating as far back as 1878,* I have expressed the opinion that the Dicotyledons could not have had their origin later than the middle Jura, and it will not sur-

* American Naturalist, vol. xii, June, 1878, p. 378; November, 1878, p. 734. In a lecture delivered February 24, 1883, at the National Museum on Plant Life of the Globe, past and present (see Science, vol. i, May 4, 1883, p. 358). American Journal of Science, third series, vol. xxvii, April, 1884, p. 302. Proc. A. A. A. S., vol xxxiii. Philadelphia Meeting, September, 1884, p. 497. Botanical Gazette, vol. ix. Indianapolis, October and November, 1884, p. 174. Fifth Annual Report U. S. Geological Survey, 1883-84, Washington, 1885, diagram, pl. lviii, facing p. 452.

prise me if the final verdict of science shall place the Potomac formation, at least the lower member in which the plants occur, within that geologic system. While the remaining types point strongly in this direction, I do not regard the Dicotyledons as at all negativing, but even more strongly suggesting this view.

Still it may be admitted that according to the ordinary modes of arguing from similar statistics, the sum of all the facts here presented would make the Potomac, considered from the point of view of the flora alone, homotaxially equivalent to the Wealden of England and North Germany, now usually included in the Cretaceous system. If the vertebrate remains are Jurassic and the flora Cretaceous we only have here another confirmation of a law exemplified in so many other American deposits, that, taking European faunas and their correlated floras as the standard of comparison, the plant life of this country is in advance of the animal life. This law has been chiefly observed in our Laramie and Tertiary deposits, but is now known to apply even to Carboniferous and Devonian floras. It is therefore to be expected that we shall find it to prevail during the Mesozoic era. If, therefore, it be finally settled that the fauna of the Potomac series is homotaxially Jurassic, and we take our starting point from Old World geology, there will be no more objection to regarding the Potomac flora as Jurassic than there is now in contemplating the Laramie flora as Cretaceous. In fact, so far as the character of the flora is concerned there is much less difficulty in the case of the Potomac than in that of the Laramie, since I have shown the Potomac flora, viewed in all its bearings, cannot be said positively to negative the reference of the formation to the Jurassic upon the evidence of the plants alone.

I do not, however, desire to be understood as arguing for the Jurassic age of the Potomac formation. The most that it is intended to claim is that, if the stratigraphical relations and the animal remains shall finally require its reference to the Jurassic, the plants do not present any serious obstacle to such reference.

ART. XIV.—*Experiments on the Effect of Magnetic Force on the Equipotential lines of an Electric Current;* by E. H. HALL, Instructor in Physics at Harvard College.

THE experiments of which the following article will give some results have been made in the Jefferson Physical Laboratory of Harvard College at occasional intervals during a period of more than three years. Some of the results have been an-

ticipated by other investigators. I desire to thank the trustees of the Bache Fund for a liberal appropriation which has been of great assistance in the prosecution of the work.

About four years ago, Mr. Shelford Bidwell published what at first appeared to be an explanation of the so-called Hall effect as being due to a thermo electric current set up between strained and unstrained portions of the same piece of metal, an effect which Thomson had discovered and which was well known. The theory thus advanced did not stand the test of examination, but it appeared from a table which Mr. Bidwell gave that, at least, the direction of the effect which magnetic force exerts upon the equipotential lines of an electric current in any given metal could be inferred from the sign of the effect produced by stress upon the thermo-electric property of the metal. Messrs. Coggeshall and W. A. Stone, of the class of 1886 in Harvard College, working with my coöperation, confirmed Mr. Bidwell's table in the case of copper, iron and zinc, but found exceptions to it in French cold-rolled steel and aluminium. No other metals were examined by them. In all cases both effects were tested. A note stating most of these facts was published in *Science*, March 27, 1885.

In this Journal for February, 1885, commenting upon the alleged reversal of the "Hall effect," which Mr. Bidwell had found in a strip of gold having two narrow longitudinal slits nearly meeting, I ventured to predict the results of experiments to be made for testing the effect of magnetic force upon the equipotential lines of an electric current in strips of metal, the forms of which may be called variations upon the type used by Mr. Bidwell.

For these experiments I have used untempered "French cold-rolled steel." This is described by the dealer who furnishes it as "celebrated for its toughness and superior quality for striking up in die or presswork." This steel is procured in the form of ribbons about 8^{cm} wide. From such a ribbon transverse strips were cut about 21^{mm} wide and in length equal to the width of the ribbon. They were all about $\frac{1}{10}^{mm}$ in thickness. Along the middle of these strips longitudinal slits were cut, in some strips one, and in others two in line separated by a certain space. (For illustrative figures see the article mentioned above.) As all the results obtained with these strips were such as might be expected from the considerations given in the article alluded to, and as these considerations have not, so far as I am aware, become the subject of criticism, it seems unnecessary at present to describe either the apparatus or results in detail. The experiments were made in February, 1885.

Long Strip and Short Strip.—At the Philadelphia meeting of the American Association in 1884 I gave reasons for think-

ing that the transverse effect would prove to be less marked near the end than in the middle of a metal strip. Similar reasons led me to suppose that the effect would, *cet. par.*, be less in a short strip, No. 16, than in a long strip, No. 15, both being of F. C. R. steel. Strip No. 15 was like those already described but without any slit. Strip No. 16 was cut from the middle of a strip like 15 and was of about the same width, but only $1{\cdot}1^{cm}$ or $1{\cdot}2^{cm}$ long. Fearing that soldering connections to the ends of so short a strip as No. 16 would change the character of the strip throughout, I used no solder with Nos. 15 and 16, but made connection with their ends by means of strips of lead pressed firmly down upon them by means of stout clamps. For No. 16 each of the lead strips was made about 4^{cm} long and as wide as the steel in order to give the main current, coming in from the connecting wires, opportunity to spread and become parallel to the edges of the strip before entering the steel. The part of No. 16 not *covered* by the lead was about 5^{mm} long. Whether the space not *touched* by the lead was longer, cannot be ascertained, but the extreme length possible was, as the dimensions already given show, about $1{\cdot}1^{cm}$. Lead was used for making connections partly because its softness made a good contact probable and partly because, lead showing very little or no transverse action of the sort under examination, its use would practically limit this transverse action to the steel strip.

The transverse connections were made, as with the other steel strips mentioned in this article thus far, by means of two stiff German-silver springs, each touching the steel at one point.

The considerations which led to the experiments with 15 and 16 were nearly as follows: The transverse action, whatever may be its explanation, makes the equipotential lines run obliquely instead of straight across the strip in which it occurs. If such a strip were short and were joined at each end to another strip in which the same action does not occur, the direction of the equipotential lines in each strip near the junction should be affected by the proximity of the other strip, so that lines in the *inert* strip would not run perfectly straight across and lines in the *active* strip would run less obliquely than they otherwise would. If a strip were short, like No. 16, this modification in the direction of the lines might be apparent throughout its whole length, so that the transverse action in a short strip might appear less powerful than in a long strip.*

May 23, 1885, Nos. 15 and 16 were tested, No. 16 first, then No. 15, finally No. 16 again. These tests were by no means accurate, but they left no doubt that the apparent transverse

* See also, upon this point, Ettingshausen and Nernst in the *Beiblätter zu den Annalen der Phys. u. Chem.*, Band xi, Stück. 5.

effect was considerably smaller in the short strip than in the long one, the difference amounting apparently to about 20 per cent.

Strips differing in Cross-Section.

Every experiment which bears upon the relation between the transverse action in a strip and the magnetic condition of the strip is of interest. Strips of any strongly magnetic metal under the conditions of these experiments become the more strongly magnetized the greater the ratio of the thickness to the width, but with the non magnetic, or weakly magnetic, metals, no such variation is observable. It is, then, important to ascertain what relation this ratio of thickness to width has upon the transverse action in magnetic and non-magnetic metals. Crosses of Norway iron, of cobalt, of nickel, of silver and of bismuth have been tested with this object in view

Silver.—From a half-dollar coin (silver 9 parts, copper 1 part) two crosses were made, the dimensions of which were approximately as follows.

	Width.			
	Main part.	Arms.	Thickness.	Length.
	mm.	mm.	mm.	mm.
No. 1	9·5	1·5	1·02	25
No. 2	0·5	0·5	1·00	23

The smallness of visible effect in these thick pieces of silver made the comparison tedious. The results obtained were nearly as follows, correction being made for the difference in thickness:

Date.	Magnetic field.	Effect in No. 1.	Effect in No. 2.
Feb. 8 or 9, 1886	9,500	100	93
Feb. 10, 1886	10,000	100	100·9
July 23, 1886	10,000	100	98·7

The strength of field is here given roughly in absolute c. g. s. units. The observations of the first day were less accurate and therefore are entitled to less weight than those of Feb. 10th and July 23d. It appears safe to conclude that in the case of silver the width of the cross has no considerable influence upon the transverse effect. The absolute magnitude of the R. P.* in this metal appeared to be about 750×10^{-6}.

$$* \text{ R. P.} = \frac{E \times T}{M \times C'}$$

where E represents the total transverse electromotive force in c. g. s. units.
M represents the intensity of the magnetic field in c. g. s. units.
C represents the strength of the direct current in c. g. s. units.
T represents the thickness of the cross in cm.

In previous papers I have not given the R. P's in absolute units, having neglected, as Professor Boltzmann has surmised (*Anzeig. d. Kais Akad. in Wien*, 1886, *Nr. X*), to change a resistance from ohms to absolute c. g. s. units. To turn the R. P's given in my article of February, 1885, into absolute c. g. s. units, it is necessary to multiply them by 10^9.

Norway iron.—Eight crosses of iron were used in such tests. Nos. 1, 3, 5 and 7 are broad; Nos. 2, 4, 6 and 8 are narrow. Nos. 1–4 were cut from one bar of ordinary Norway iron such as blacksmiths use. Nos. 5–8 were cut from another bar of the same kind.

Of these bars the ends, which had possibly been heated and hammered more than the other portions, were avoided in cutting out the crosses. The dimensions of the crosses, as given below are only roughly correct.

	Width.		Thickness.	Length.	
	Main part. [near arms]	Arms. [near main part]	Main part. [near arms.]	Main part.	Arms. [each.]
No. 1	7·0^{mm}	2·0^{mm}	2·20^{mm}	40^{mm}	6^{mm}
2	0·5	0·5	2·30	42	9
3	9·5	2·0	2·86	43	4
4	0·5	0·5	2·85	42	7
5	8·0	2·0	0·50	31	4
6	0·5	0·5	0·48	30	9
7	9·0	2·0	3·00	38	5
8	0·5	0·5	3·00	33	9

Nos. 1 and 2 were compared June 18th and 19th, 1885. The strength of magnetic field used is not recorded. The comparison, which was very rough, gave

$$\frac{\text{R. P. in narrow cross}}{\text{R. P. in broad cross}} = 1{\cdot}5.$$

Nos. 3 and 4 were compared in August, 1885, in a magnetic field the intensity of which was about 8000 or 9000 (c. g. s.). This test, which also was rough, gave

$$\frac{\text{R. P. in narrow cross}}{\text{R. P. in broad cross}} = 1{\cdot}3.$$

Nos. 5–8 were tested Dec. 31st, 1885, and Jan. 1st, 1886. The order of trial on Dec. 31st was Nos. 7, 8, 6, 5, 5, 6, 8, 7. The purpose of this arrangement was to eliminate, so far as practicable, from the result of the trial error arising from changes in certain factors of the test during the progress of the experiment, such as a possible variation in the sensitiveness of the astatic galvanometer used to measure the transverse current or a gradual weakening of the magnetic field. An occasional observation of the time of vibration of the needle in the astatic galvanometer showed that no great change was occurring in the sensitiveness of this instrument. The weakening of the magnetic field in the course of the day was probably less than 10 per cent. By combining the two observations made with each cross four results are obtained which should

be nearly free from error due to such changes. These results are given below in numbers which are merely relative, the smallest being made 100.

Strip.		R. P. on arbitrary scale.	Mean.
No. 5		100+	100
5		100−	
6		153·4	154·3
6		155·3	
7	(see below)	131	142·5
7		154	
8		318·3	323·2
8		328·1	

The intensity of the magnetic field in these experiments was probably between 5500 and 6000 (c. g. s.). A rough test indicated that the R. P. of No. 5 was about 9000×10^{-6}.

The two tests with No. 5, which came close together in time agree best. Next in agreement come the tests with No. 6, next those with No. 8, and finally the two trials of No. 7, which came farthest apart in time, are widely divergent in results. The divergence here is so great that a new comparison of Nos. 7 and 8 was made the next day, the magnetic field being kept for this purpose about the same as on Dec. 31st, although later in the day a stronger field was used. This comparison gave

$$\frac{\text{R. P. of No. 8}}{\text{R. P. of No. 7}} = \frac{1075}{506}, \text{ or } \frac{323}{152}.$$

The mean of this result and that of Dec. 31st gives

$$\frac{\text{R. P. of No. 8}}{\text{R. P. of No. 7}} = \frac{323}{147}$$

in a magnetic field of about 6000 (c. g. s.).

The influence of the shape of the specimen examined is quite evident in all the experiments upon Norway iron thus far described. The most important part of a cross is, no doubt, the region made up of the bases of the arms and the portion of the main strip between and near the arms. This region may be called the *effective portion* of the cross. All these experiments upon Norway iron show that a cross of this metal in which the effective portion has the ratio *thickness÷width* comparatively large, shows a comparatively large R. P. This fact is brought out in a particularly interesting manner by the experiments of Dec. 31st and Jan. 1st, just described. From the dimensions already given it is evident that the ratio *thickness÷width*, is least in No. 5 and greatest in No. 8. In No. 7 it is greater than in No. 5 and in No. 6 greater than in No. 7. Accordingly we are prepared to find, and do find, that the

R. P. is smallest in No. 5, larger in No. 7, still larger in No. 6, and largest in No. 8.*

In the test already described the R. P. of No. 8 was, in fact, three times as great as that of No. 5, and as the latter was quite strongly magnetized, it seemed not unlikely that No. 8 was in a condition approaching what is called the state of *magnetic saturation.* If this were the case, No. 8 probably would, when placed in a stronger magnetic field than that used Dec. 31st, suffer a diminution of its R. P., while Nos. 5, 6 and 7 should show less or no diminution of this sort under similar circumstances. Accordingly on Jan. 1st, 48 cells, 6 abreast, were used in the magnet circuit, the number used the day before having been 30, 6 abreast. This brought the magnetic field up to about 7000. The four crosses were then tested essentially as on Dec. 21st, the order being as before, Nos. 7, 8, 6, 5, 5, 6, 8, 7. The numbers given by this trial, like those obtained Dec. 31st, are only comparative. They do not represent the absolute values of the R. P's, and for convenience they have been reduced to such a scale as to give No. 5 the same representative number that it had in the results of Dec. 31st.

Results of Jan. 1st, 1886, with magnetic field about 7100 (c. g. s.) :—

	R. P. on arbitrary scale.	Mean.
No. 5	101 99	100
6	152 154	153
7	144 148	146
8	260 270	265

On comparing these figures with those given above, it appears that the relative standing of Nos. 5, 6 and 7 was affected very slightly, by going from the weaker to the stronger magnetic field, but No. 8 shows a great falling off. So great, in fact, was this charge in No. 8, that the observations made at this time did not clearly show whether the magnetic field of about 7100 produced upon the equipotential lines of the electric current in this cross an effect greater or less than that produced by a field of less than 6000. But experiments made Aug. 3d, 1886, with the same cross indicate that a field of 10,500 produces an effect one or two per cent greater than a field of 8000.

* The results obtained with No. 7 were so variable on these two days that its place among the others cannot be assigned with confidence. Later experiments make its R. P. relatively larger.

On Jan. 7th, 1888, Nos. 5, 6 and 8, were tested in a field of about 3800. The relative sizes of the R. P's in this field are represented by the following numbers, no one of which is probably in error more than 5 per cent of itself:—

For No. 5	100
6	158
8	436

It will be seen that the relative standing of Nos. 5 and 6 is not seriously changed, although No. 6 gains a little as was to be expected. No. 8 makes a large gain.

If in the results of these tests, we look for something more than the general influence of shape upon transverse effect, and inquire whether the relative intensity of magnetization in each cross corresponds accurately to the relative magnitude of the R. P. therein, we find it impossible to determine exactly the intensity of magnetization in the several crosses, as they do not closely resemble any of the forms for which accurate calculation has been made. It may be worth while, however, to note what are the results of calculation in the case of certain typical forms.

We find in Maxwell, Art. 400, that in general

$$B = (1+4\pi\varkappa)\ H \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where B is the intensity of "magnetic induction through the the body," H the "magnetic force" ("polar definition") within the body and $\varkappa$ is Neumann's coefficient, a quantity which Maxwell supposed to be about 30 for soft iron, but which Rowland has found to be at times much greater than that in Norway iron.

Letting H represent the magnetic force directly due to the poles of the electro-magnet, we find from Maxwell, Art. 438, that in a cylinder placed between these poles so as to become magnetized transversely this relation holds

$$H=\mathrm{H}-2\pi k H, \text{ or } H=\frac{\mathrm{H}}{1+2\pi\varkappa}. \quad . \quad . \quad . \quad . \quad (2)$$

From (1) and (2) we find

$$B=\mathrm{H}\frac{1+4\pi\varkappa}{1+2\pi\varkappa}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

For ordinary values of $\varkappa$ we find approximately for this cylinder

$$B=2\mathrm{H}.$$

In case of a sphere we find

$$B=\text{approximately } 3\ \mathrm{H}.$$

In a thin disk magnetized longitudinally, i. e. in a direction normal to the faces, the law is $B=H$. The *effective portion* of cross No. 5 is fairly well represented by such a disk, and we shall assume that with this cross B was nearly equal to H.

In case of a disk magnetized *transversely*, i. e. parallel to its faces, the diameter being to the length as 6 to 1,

$$B=\text{approximately } 8\,H.$$

As the thickness of cross No. 8 was about 3^{mm} and as the width of the main part was in general about $0{\cdot}5^{mm}$, it might be thought that this cross presented a case similar to this latter disk, but it must be remembered that the *effective portion* included the bases of the arms. It is likely, too, that both the main part and the arms were somewhat more than $0{\cdot}5^{mm}$ wide at the junction. The case lies, probably, between that of the disk magnetized transversely and that of the sphere, but nearer that of the sphere. It seems not unlikely then, that in a field of moderate strength, such as would not bring either cross near to the condition of "saturation," No 8 might become four or five times as strongly magnetized as No. 5. It will be remembered that in the experiments of Jan. 7th, with a field of moderate intensity the R. P. of No. 8 was about $4\frac{1}{3}$ times as great as that of No. 5.

The primary object of these experiments was to obtain new evidence bearing upon the question whether the transverse effect studied is due to a distortion of the cross as a whole under the combined action of the ordinary "pondero-motive force," as Mr. Bidwell and, doubtless, others have supposed, or to some internal interaction, which for want of a better term may be called *molecular*, of the magnetic and electric states of the conductor. The results obtained lend no support to the former of these two hypotheses, but they are in complete accord with the latter, which must, I think, be regarded as established.

Wishing to study still further the connection between the internal magnetic condition of iron and the transverse effect in it, I have made recently a series of experiments comparing the behavior of the two broad crosses Nos. 5 and 7. Instead of depending here upon a calculation of the ratio of the magnetic inductions in the two, I have tried to measure this roughly by a method which I will describe somewhat fully, as I shall probably make use of it in future experiments. A loop of thin well-covered wire (the diameter to outside of covering being about $0{\cdot}25^{mm}$) was placed flat upon each of these crosses between the arms, was pressed well down and secured in place and shape with the usual cement of beeswax and rosin. Each of these loops was somewhat elliptical in shape, that on No. 5 being about $7{\cdot}4^{mm}$ wide and $12{\cdot}4^{mm}$ long, and the one on No. 7

about 8mm wide and 12mm long. In each case the shortest diameter reached nearly from arm to arm. Care was taken to prevent either loop from overhanging the edge of the cross at any point. The loops were made as equal circles by winding them upon a cylinder about 1cm in diameter. They must have had nearly equal areas in their final forms. After somewhat careful measurements the final area of each was estimated at 0·78 sq. cm. This estimate may be wrong by several per cent. for either or both loops.

The plan was to put in turn Nos. 5 and 7 between the poles of the electromagnet and compare, by means of a ballistic galvanometer, the induction currents produced in the loops by suddenly reversing the direction of the magnetic field. It is believed that the ratio of these two induction currents does not differ many per cent from the ratio which the intensity of magnetic induction through the effective portion of one cross bears to that through the effective portion of the other cross.

Comparisons were also made between the induction currents obtained with each loop and those obtained with a coil of four circular turns having a total area about 5·24 sq. cm., this latter coil being the one used to determine the strength of the field when no magnetic metal was between the poles. This coil will be called the *test-coil*. Its ordinary use was not to remain between the poles and give an induction-current upon reversal of the magnet-current, but to be withdrawn suddenly from the field while the magnet remained in full force. This latter use is of course the better one when it can be employed, for it cannot always be assumed that the visible induction effect obtained by reversal will indicate the true change of strength of the field. As this particular matter had to be investigated with some care, I will give the results, although the following table does not attempt great accuracy.

M = intensity of field in c. g. s. units.
d = swing of needle on pulling test-coil out of field.
D = swing of needle on reversing magnet current, test-coil remaining between poles.

M	d	$2 \times d$	D
2300	0°·644	1°·29	1°·16
4800	1·35	2·70	2·43
8900	2·52	5·04	4·87
8100	2·32	4·64	4·38
8500	2·43	4·86	4·60
8700	2·51	5·02	4·83
9200	2·61	5·22	5·13
9200	2·64	5·28	5·20
9250	2·62	5·24	5·14
9700	2·82	5·64	5·54

The first three of these comparisons were carefully made; the others less carefully. In the second the electro-magnet was worked by a battery current. In all the others the current came from a Gramme dynamo. The coil was always withdrawn from the field very briskly on the end of a lever which carried it three or four feet away from the magnet. The reversal was effected by means of a mercury commutator, which was worked by pulling a string and probably turned in a quarter of a second or less. The time of a single swing of the ballistic needle from one elongation to the next was small, not much more than three seconds. The discrepancy between the results of the two methods when comparatively weak fields are used is very great, about 10 per cent. The difference diminishes as stronger and stronger fields are used, and in fields above 9000 appears to be not greater than 2 per cent. Direct comparisons of the two methods were not made in fields much stronger than those given in the table. Indirect comparisons made in a field about 12,000 and in another about 16,000 indicate that the difference continues to decrease as the field increases in strength.

It has been already stated, that the loops on the iron crosses 5 and 7 gave their induction currents by remaining between the poles when the magnet current was reversed. The indications which they gave were therefore subject to a correction in order to make them comparable with those given by the test-coil upon sudden withdrawal from the magnetic field. In the results to be given this correction will be applied in accordance with the indications of the table above. It will be assumed that the proper correction in the strongest fields used is 1 per cent.

The main object of the whole series of experiments being to test the relation between the magnetic induction through the crosses and the transverse effect in them, it was desirable to get the induction current from the loop as nearly as possible simultaneously with the measurement of the transverse current from the arms of the cross. This latter current was measured by a series of readings of an astatic galvanometer, the magnet current being reversed after each reading. At every such reversal, the swing of the ballistic needle due to the induction current from the loop of wire was noted, so that the two series of observations, one upon the transverse effect, the other upon the induction, were carried on at the same time. To avoid error due to direct action* of the electromagnet upon the ballistic and the astatic galvanometers, or to induction in parts of the ballistic galvanometer circuit which

* When the magnet was strongest its direct action upon the astatic galvanometer about 140 feet distant was very important.

were not intended to be subject to such induction, a complete determination with any particular strength of magnetic field required two sets of observations, one made with the cross facing east (the axis of the magnet being nearly east and west), the other made with the cross facing west, all electrical connections being the same throughout the two sets and the condition of the ballistic and the astatic galvanometers remaining, as nearly as practicable, unchanged.

When magnet currents of moderate strength, *e. g.*, 7 or 8 Ampères, were used, two complementary sets were usually made with an interval of not more than 5 or 10 minutes between them, and in such cases the strength of the field was not measured by means of the *test-coil* until the observations with the cross were finished. When the strongest currents were used the magnet became heated rapidly, and thermo-electric effects in the astatic galvanometer circuit soon began to show. In these cases three observations of the astatic galvanometer, right, left, right, or left, right, left, as the case might be, the readings being 1½ minutes apart, were all that could profitably be made on the transverse current. The strength of field was then taken with the test-coil, but by the time this had been done, the magnet had become so hot that the complementary set of observations with the cross faced about could not be made until several hours had passed. When the second set was made the strength of the field was measured again. The magnet current was closely watched by means of an ammeter. This made possible certain corrections and reductions required by the fact that this current and hence the magnetic field could not be kept perfectly constant. It appeared that when the currents were strongest it required about 4 per cent increase in current to produce an increase of 1 per cent in the strength of field. A field of 8000 was increased about 0·6 per cent by an increase of 1 per cent in the strength of the current. A Gramme dynamo supplied the current.

The temperature of the crosses during the experiments is a matter of some doubt. The poles of the magnet have been about 7^{mm} apart in all observations with crosses 5 and 7, since June 1, 1888. No. 7, with the glass upon which it is mounted and the wax in which it is imbedded, makes a mass which nearly fills the space between the poles. No. 5, with its mounting, is considerably thinner. Neither *cross* could possibly come into actual contact with the poles. A few turns of coarse thread were wound around the plates to prevent or impair contact between the glass and the pole and so to impede the flow of heat from pole to cross. The crosses, even with the electric current which each was transmitting, prob-

ably became heated much more slowly than a thermometer which was kept in the bore of the electromagnet. This thermometer rose usually about 5° Centigrade during one set of observations on the transverse current when the strongest magnetic fields were used. If it be assumed that each of the crosses rose in temperature one-half as fast as this thermometer, the conclusion is that the mean temperature of the cross during such a set of observations was not more than one or two centigrade degrees above its temperature at the beginning. This initial temperature was probably known within one or two degrees usually. According to experiments with other specimens of iron and steel,* a change of two degrees in temperature should cause a change of about 1 per cent in the transverse effect in the crosses It is improbable that our conclusions will be seriously affected by the uncertainty as to temperature.

The sensitiveness of the astatic galvanometer was another variable. This was determined three times in connection with this series of experiments by passing a known current through the galvanometer and noting the deflection produced.

The results found were:

	Sensitiveness.
June 4th	100
June 13th	101·4
June 20th	102·6

In the meantime the galvanometer was not touched, so far as I am aware, by anyone but myself and I made no intentional changes in its condition. In making reductions it will be assumed that its change of sensitiveness was uniform from one date to the next. This may leave room for an error of 1 or 2 per cent at some points.

Rough observations of the temperature of the astatic galvanometer circuit were made in order to correct for changes of resistance in this circuit.

A rough preliminary series of experiments was made, beginning with fields of moderate strength and proceeding to stronger and stronger ones, but the troublesome character of the investigation and the pressure of other work have made it necessary to limit the more careful and thorough study to the very strongest fields and to those of medium strength. Even with this limitation the results reached are not in all respects harmonious and satisfactory. The data are given below in some detail in order to show the scope of the corrections and reductions which have been made.

In the tables below—

* This Journal, Feb., 1885.

A = mean reading of ammeter during observations on transverse current. These readings may for our purpose be considered as giving the strength of the magnet current in amperes. This probably understates the current somewhat.

A′ = same during measurement of intensity of magnetic field by means of test-coil.

R = change of reading on scale of ballistic galvanometer produced by induction current from loop on cross. The number of such divisions corresponding to 1° of actual deflection is about 3·6.

M. F. = same produced by induction current from test-coil on being pulled out from magnetic field. These readings reduced to correspond with E. I. at 7.6 and then multiplied by 1000 give approximately the intensity of the magnetic field in absolute, c. g. s. units.

E. I. = same produced by earth inductor in circuit with test-coil and loop on cross.

D = movement from extreme to extreme of spot of light on scale of astatic galvanometer used to measure transverse current from cross. 1° actual deflection = about 3·6 divisions on this scale.

θ = reading of tangent galvanometer measuring direct current through cross. Reduction factor of this galvanometer = about 0·3. Hence direct current = about 2 amperes.

t = temperature of astatic galvanometer circuit.

t' = temperature of cross.

No. 5.

	A	R	D	θ	E. I.	M. F.	A′	t	t'
June 4, 1888.*	24·75	5·05	9·255	35° 46′	7·58	16·47	23·75	27	30
June 5.	26·30	4·65	8·770	36° 37′	7·56	16·83	25·50	27	22
Mean.	25·5	4·85	9·01	36° 12′	7·57	16·65	24·6	27	26
June 8.	24·4	4·96	8·71	36° 23′	7·70	16·27	23·2	29	20
June 8.	25·1	4·93	9·30	36° 28′	7·70	16·27	24·0	29½	28
Mean.	24·8	4·95	9·01	36° 26′	7·70	16·27	23·6	29	24

Reducing the two means to uniform conditions by methods self-evident or already indicated, we find

	A	R	D	θ	E. I.	M. F.	A′	t	t'
June 4 and 5.	25	4·84	9·06	36°	7·60	16·18	25	25	28
June 8.	25	4·89	9·22	36°	7·60	16·20	25	25	28
Mean.	25	4·87	9·14	36°	7·60	16·5	25	25	28

No. 7.

	A	R	D	θ	E. I.	M. F.	A′	t	t'
June 4.	25·2	6·84	1·955	36° 47′	7·68	16·52	23·35	24°	24°
June 5.	25·1	6·56	1·975	37° 57′	7·68	16·65	24·03	29°	31°
Mean.	25·15	6·70	1·970	37° 22′	7·68	16·59	23·69	26½	27½
June 7.	23·92	6·35	2·05	37° 25′	7·74	16·54	23·50	29	26
June 7.	24·4	6·36	1·70	37° 13′	7·82	16·64	23·60	30	31
Mean.	24·16	6·36	1·875	37° 19′	7·78	16·59	23·55	29½	28½

* The { embraces complementary sets.

June 11.	24·97	7·00	1·985	36° 23′	7·84	16·39	23·80	27	25
June 11.	24·95	6·82	1·625	36° 45′	7·86	16·57	24·27	28½	28½
Mean.	24·96	6·91	1·805	36° 34′	7·85	16·48	24·03	28	27

Reducing the three means to uniform conditions we find

	A	R	D	θ	E. I.	M. F.	A′	t	t'
June 4 and 5.	25	6·62	1·886	36°	7·60	16·6	25	25	28
June 7.	25	6·26	1·825	36°	7·60	16·5	25	25	28
June 11.	25	6·69	1·778	36°	7·60	16·1	25	25	28
Mean.	25	6·52	1·86	36°	7·60	16·4	25	25	28

The observations made with weaker magnetic fields will be given with somewhat less detail:

No. 5.

	A	R	D	θ	E. I.	M. F.	A′	t	t'
June 14.	8.21	2·81	5·00	35° 13′	7·75	9·44	8·22	28	27
Reduced.	8·33	2·80	5·20	36° 0′	7·60	9·38	8·33	25	28

No. 7.

June 14.	8·37	4·72	1·377	36° 23′	7·83	9·51	8·3	28	23
June 14.	8·20	4·63	1·442	36° 1′	7·80	9·41	8·12	28	31
Reduced mean.	8·33	4·57	1·409	36°	7·60	9·34	8·33	25	28

No. 5.

June 18.	7·34	2·63	4·86	34° 28′	7·84	8·76	7·15	31	32
Reduced.	7·25	2·53	4·98	36°	7·60	8·56	7·25	25	28

No. 7.

June 18.	7·72	4·51	1·337	35° 9′	7·85	9·02	7·55	31°	29°
June 18.	6·74	4·11	1·332	35° 13′	7·85	8·35	6·52	31°	35°
Reduced mean.	7·25	4·18	1·349	36° 0′	7·60	8·57	7·25	25°	28°

In the above tables no corrections have been applied with reference to the facts, already discussed, that the test-coil is not used in just the same manner as the loops on the crosses, or to the further fact that the readings of the ballistic galvanometer scale are proportional to the tangent of twice the deflection instead of being proportional to the sine of one-half the deflection. In the table which follows, and which is in the main derived from those going before, corrections are applied with these points in view.

No. 5.

Int. of mag. field.	D × (thickness of cross) / Int. of mag. field.	R (corrected) / 2 × area of loop.		M. F. (corrected) / Area of test-coil.		Mag. ind. in cross / Mag. ind. of field.	D × (thickness of cross) / R (corrected).	
16,350	280×10^{-9}	3·15	÷	3·12	=	1·01	·929	
9,360	278×10^{-9}	1·83	÷	1·79	=	1·02	·910	.928
8,540	292×10^{-9}	1·69	÷	1·63	=	1·04	·947	
4,900 (July 3,'88: no observations on tr'nsv'rse current.)						1·02	----	

No. 7.

16,250	343×10^{-9}	4·22	+ 3·10	= 1·36.	·848		
9,320	454×10^{-9}	2·99	+ 1·78	= 1·68	·907	}	919
8,550	473×10^{-9}	2·79	+ 1·63	= 1·71	.931	}	
4,900 (July 3.)		----	----	1·75	----		

The last column shows that with fields of medium strength the relatively greater transverse effect in the thick cross corresponds closely to the more intense magnetic induction through this cross.

The difference between the second and third values for No. 5 in this column, and also that between the second and third values for No. 7, must be regarded as mainly accidental, a fact which shows the need of caution in drawing numerical conclusions from this series of results. It appears, however, that the transverse effect in the thin cross, No. 5, maintains a nearly constant ratio to the magnetic induction through the same when the magnetizing field is increased from about 9000 to more than 16,000; but that with a similar increase of magnetizing field the transverse effect in the thick cross, which attains an extremely high degree of magnetization, does not increase enough to maintain unchanged its ratio to the magnetic induction through the cross.

(To be continued.)

ART. XV.—*Analyses of the Waters of some American Alkali Lakes;* by THOMAS M. CHATARD.

IN the course of the geological examination, by the U. S. Geological Survey, of the Great Basin or country lying between the Rocky Mountains and the Sierra Nevada, samples of the waters of most of the lakes of that section were collected and sent for analysis to the laboratory of the Survey. Many of these analyses were published in Bulletin No. 9, U. S. Geol. Survey, but when I began a special study of the more important sources of natural alkalies, for the purpose of preparing the way for their practical utilization, a re-examination was, in some cases, deemed advisable and samples were also obtained from Owen's Lake, California, a locality not visited by the Great Basin party.

The four analyses here given represent the most important alkali lakes so far known and as the waters of two of them are now being utilized, it is believed that the information will prove of interest.

The analytical methods used are, in general, well known. The carbonic anhydride was, in all cases, determined by dis-

tillation, being collected and weighed in a potash bulb. For the boric acid, in the water of Owen's Lake, the excellent method of Gooch* was followed; for the Mono and Ragtown waters the process of Stromeyer, with modifications of my own, was used, but, though giving very fair results, the process cannot be compared for ease, simplicity and accuracy with the former method.

The determination of the alkalies in such very dense waters was, at first, found to be difficult, owing to the large quantities necessarily taken. To get determinations which shall be fairly accurate when referred to a liter, portions of not less than 50 c.c. should be taken, the water in all cases being carefully weighed. The amount of alkaline chlorides corresponding to 50 c.c. of such waters is very large, and, when the final evaporations are being made, there is great liability to loss, owing to the formation of a salt crust on the surface of the liquid and subsequent spirting caused by steam and ammonia vapor produced under the crust. This takes place no matter how carefully the evaporation be carried on, and many determinations were thus lost.

The use of hydrochloric acid enables us, however, to completely obviate this difficulty. The purified alkaline chlorides are to be evaporated till crystallization begins; the platinum vessel is then removed from the water bath and an equal bulk of very pure, highly concentrated hydrochloric acid added to the solution. A copious precipitation of finely granular salts at once ensues, and, on replacing the vessel on the water bath, evaporation goes on quietly and rapidly, no salt crust is formed, and when the final heating is given, little decrepitation occurs. In this manner, it is as easy to handle several grams of chlorides and to obtain accurate determinations as it is when we have to deal with the far smaller quantities usual in mineral analysis.

Of the four lakes to be considered, the most northern one is Abert Lake, in south-eastern Oregon. The sample analysed was "collected by H. T. Biddle at middle of west side of lake, one foot below surface, 30–40 feet from shore, September, 1887." The total quantity at my disposal was about 200 c.c., an amount too small for any extended research, but sufficient for all practical purposes. For each determination, 25 c.c. = 25·7792 grams were taken.

Specific Gravity, 1·03117 at 19.8°.

* Gooch, Proc. Am. Acad. Sci., 1886, p. 167.

	Contents in 25 c.c. A.	B.	Average.	In 1 Liter.	Per cent.	Hypothetical Composition.		Per cent.
SiO_2	·0063	·0053	·00580	·232	·59	SiO_2	·232	·59
K	·0133	·0136	·01345	·538	1·37	KCl	1·027	2·62
Na	·3674	·3671	·36725	14·690	37.51	NaCl	21·380	54·58
SO_3	·0148	·0146	·01470	·588	1·50	Na_2SO_4	1·050	2·68
O	·0030	·0029	·00295	·118	·30	Na_2CO_3	10·611	27·09
CO_2	·1755	·1757	·17560	7·024	17·93	$NaHCO_3$	4·872	12·44
O	·0615	·0616	·06155	2·462	6·28		39·172	100·00
Cl	·3365	·3366	·33655	13·462	34·67			
H				·058	·15			
				39·172	100·00			

Proceeding southwardly, we have next the "Big Soda Lake" near Ragtown, Churchill Co., Nevada. This, with the adjoining "Little Soda Lake," has been very fully described by King* and by Russell,† and my own observations, during my short stay at this place, were confined to the technical aspects of the manufacture of carbonate of soda, which is carried on at both lakes.

The sample of the water of the "Big Lake," of which the analysis is here given, was collected by Mr. Russell in 1881, and was taken at the depth of one foot. The analysis was made in 1884 and was published in Bulletin No. 9, U. S. Geol. Survey, the CO_2 being then determined by difference. Since then it has been carefully determined in duplicate, with the following results.

Specific Gravity, 1·0995 at 19·8°.

	In 1 Liter.	Per cent.	Hypothet. Composition.		Per cent.
SiO_2	·304	·24	SiO_2	·304	·24
Mg	·270	·21	$MgCO_3$	·862	·67
K	2·520	1·95	KCl	4·817	3·73
Na	45·840	35·53	NaCl	71·507	55·42
B_4O_7	·314	·24	Na_2SO_4	19·170	14·86
SO_4	12·960	10·05	$Na_4B_4O_7$	·402	·31
CO_3	20·934	16·23	Na_2CO_3	16·731	12·97
Cl	45·690	35·41	$NaHCO_3$	15·220	11·80
H	·181	·14		129·13	100·00
	129·013	100·00			

Mono Lake, Mono Co., California, is next in succession. This locality is described at length by Mr. I. C. Russell in his paper, "The Quaternary History of Mono Valley, California," which will shortly appear in the 8th Annual Report of the U. S. Geological Survey; for the present it suffices to say that this large body of water, of a composition so favorable to utilization, is, for practical purposes, inaccessible, and that the high altitude and consequent shortness of the evaporating sea-

* King, Clarence, U. S. Geol. Expl. 40th Parallel, vol. i, pp. 510–513.

† Russell, I. C., Geological History of Lake Lahontan, U. S. Geological Survey. Monographs XI.

son would, under any circumstances, render the success of any industry established there very doubtful.

The sample analyzed was collected by Mr. Russell in 1882 and was taken at the depth of one foot, on east side of lake.

Specific gravity, 1·045 at 15·5°.

	In 1 Liter.	Per cent.
SiO_2	·0700	·12
K	·9614	1·79
Na	19·6853	36·81
Ca	·0200	·037
Mg	·0551	.10
$(Al_2Fe_2)O_3$	·0030	·005
SO_4	6·6720	12·480
CO_3	13·6903	25·61
B_4O_7	·1600	·30
Cl	12·1036	22·64
H	·0522	·10
	53·4729	100·00

Hypothet. Composition.		Per cent.
SiO_2	·0700	·13
$(Al_2Fe_2)O_3$	·0030	·005
$CaCO_3$	·0500	·09
$MgCO_3$	·1928	·36
$Na_4B_4O_7$	·2071	·39
KCl	1·8365	3·44
NaCl	18·5033	34·60
Na_2SO_4	9·8690	18·45
Na_2CO_3	18·3556	34·33
$NaHCO_3$	4·3856	8·20
	53·4729	100·00

Finally, at the southern end of the series, we have Owen's Lake, Inyo Co., California. This lake has been described by Oscar Loew in Wheeler's Report for 1876, pages 189–194, and upon it most of my field work for 1886 and 1887 has been done. Its greatest dimensions, as given by Loew, are seventeen miles long by nine miles wide, its greatest depth fifty-one feet, and it contains, according to his calculation, 22,000,000 tons of carbonate of soda. The Inyo Development Co. has begun the manufacture of soda at this point and to it I am indebted for every needed facility for making observations on the evaporation of the water and on the various salts obtained by its fractional crystallization. These products, together with others since obtained, are under examination and the results will be published later.

The sample analyzed was taken by myself, Sept. 17, 1886. Portions of 100 c.c. were taken for each determination, the duplicates agreeing very closely.

Specific gravity, 1·062 at 25°.

	In 1 Liter.	Per cent.
SiO_2	·220	·28
K	1·644	2·13
Na	28·500	36·96
Ca	·014	·02
Mg	·005	----
Fe_2O_3	·014	·02
Al_2O_3	·024	·03
SO_4	7·505	9·73
B_4O_7	·367	·49
CO_3	19·398	25·16
Cl	19·344	25·09
H	·063	·10
	77·098	100·00

Hypothet. Composition.		Per cent.
SiO_2	·220	·28
$(Al_2Fe_2)O_3$	·038	·13
$(CaMg)CO_3$	·055	
$Na_4B_4O_7$	·475	·63
KCl	3·137	4·07
NaCl	29·415	38·16
Na_2SO_4	11·080	14·38
Na_2CO_3	26·963	34·95
$NaHCO_3$	5·715	7·40
	77·098	100·00

In comparing such analyses, to determine the practical value of a given water for soda making, the relation of the amount of sulphate to the total amount of carbonate is of the greatest importance, since the greater the relative amount of sulphate, the more difficult it will be to obtain a high grade carbonate by simple solar evaporation. If this relative amount is small, a large excess of chlorides may be present without materially complicating the process. The relation between the monocarbonate and the bicarbonate should, for best results, be a molecule of each plus an excess of monocarbonate. The amount of necessary excess is not yet accurately determined but is probably under a molecule. Judged by this standard, the water of Abert Lake is the best, Ragtown the worst, of those here considered, while Owen's Lake, occupying a middle position as regards purity, is, owing to its geographical position and climatic environment, probably the one best adapted for practical utilization.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Molecular weight of Nitrogen peroxide.*—Vapor density methods appear incapable of establishing definitely the molecular constitution of nitrogen peroxide, although rendering it probable that at low temperatures this substance is represented by the formula N_2O_4. Ramsay has therefore applied to this question a method founded upon the researches of Raoult, which have proved that the depression of the freezing point of a liquid caused by the presence of dissolved liquid or solid is proportional to the absolute amount of substance dissolved and inversely proportional to its molecular weight. Raoult found the law to hold almost universally, the exceptions being very few. Thus using glacial acetic acid as the solvent, he found that out of 150 substances examined, scarcely half a dozen gave abnormal results. Ramsay's apparatus consisted of a wide test tube closed with a rubber cork, having two holes, through one of which a thermometer passes and through the other a glass tube in which plays a stirrer. The apparatus is placed in a beaker, and by adding hot or cold water, its temperature may be raised above or depressed below the freezing point of the solvent. In a first experiment 41·02 grams of glacial acetic acid were weighed into the apparatus, its melting point being 16·680°. A small bulb of nitrogen peroxide, containing 0·378 gram, was then broken in the acetic acid by means of the stirrer, and the melting point again observed. It was found to be 16·300°, having been lowered 0·380°. Hence one per cent of the peroxide would have lowered the melting point

0·4214°. Since 0·4214°×94·6=39, the constant obtained by Raoult for acetic acid, it follows that the molecular weight of the peroxide from this experiment is 94·6. A second quantity of 0·5085 gram peroxide was then crushed in the apparatus and lowered the melting point to 15·825°; corresponding to the molecular weight 98·58. Other determinations gave 92·11, 92·07, 93·18, 90·29. In a second experiment 40·05 grams of acetic acid, melting at 16·675°, had its melting point lowered to 15·768° by 0·893 gram of the peroxide; corresponding to a molecular weight of 95·87. Hence the author concludes that the molecular weight of nitrogen peroxide in the liquid state at about 16° is 92 and that its formula is N_2O_4. Moreover since, in the above experiments, the relative number of molecules of the peroxide in a given volume of acetic acid was decreased from 8·97 to 0·92 without changing its molecular weight it would appear that no dissociation of the peroxide takes place on dilution. Experiments with nitrogen trioxide, made by passing NO through N_2O_4 dissolved in acetic acid gave no reliable results since at 16° the trioxide was dissociated.—*J. Chem. Soc.*, liii, 621, June, 1888. G. F. B.

2. *Index of refraction of metals.*—A. KUNDT gives a brief account of his method of making metallic prisms of extremely small angle, which allow light to pass through. Most of the metallic prisms were deposited by electrolysis upon platinized glass. To accomplish this it was necessary to obtain a homogeneous and plane surface of platinized glass. After many trials Kundt succeeded in fusing with the glass, at a low red heat, the platinum layer. Vertically over a strip of this platinized glass, which was placed horizontally, is an electrode of the metal which is to be deposited upon the platinum. This electrode makes a small angle with the horizontal surface and includes a capillary layer of a suitable electrolyte. Frequently fifty or more trials have to be made before a suitable transparent wedge of the metal is formed which can be used to refract light. The prisms were also formed by exposing a glass plate to platinum wire raised to a white heat by an electrical current. The glass becomes covered with a layer of finely divided platinum. In order to form the wedge-shaped surface a piece of platinum foil 0·015^{mm} thick, 6^{mm} broad and about 45^{mm} long was placed with the broad sides vertical closely over a horizontal glass plate. In this way a double wedge is formed on the glass, consisting of a mixture of platinum oxide and platinum. By slight warming, the mixture can be converted into pure platinum. These metallic wedges were also formed in a vacuum by the above process, with very small angle of prism. The simple expression for index of refraction is $N=\frac{\alpha+\delta}{\delta}$, in which N is index of refraction, δ is angle of prism and α the deviation of the ray. These small quantities were measured by the micrometer of a Meyerstein spectrometer. Various control methods were employed to secure accuracy of measurement. The velocity of light in silver is nearly four times greater than

in a vacuum. The dispersion in silver is however not great. The velocity in gold and copper is also greater than in a vacuum, and the dispersion normal. In other metals the dispersion was found to be abnormal. The theoretical conclusions of Beer and Voigt in so far agree with the results of Kundt to a remarkable degree. If we call the velocity of light in silver 100, we have the following:

Silver.	Gold.	Copper.	Platinum.	Iron.	Nickel.	Bismuth.
100	71	60	15·3	14·9	12·4	10·3

With the exception of bismuth, this series is the same as that of the electrical resistance of metals. The number for copper however is somewhat small and may be due to impurity. The ratio of the heat conduction and electrical resistance of bismuth is still in question. From the above numbers one is tempted to conclude that the electrical resistance is proportional to the velocity of light of great wave length. We have here a relation between electricity—conduction of heat and velocity of light—Kundt is tempted to believe that the slowness of heat conduction in metals is due to the radiation from one layer to the adjoining, whereas the radiation itself in metals has the velocity of light. What we call electricity moves in a conductor with the velocity of light.—*Ann. der Physik und Chemie*, pp. 469–489, No. 7, 1888.

J. T.

3. *Resistance of square bars to Torsion.*—T. I. Dewar calls attention to an error which has crept into various articles, including Prof. Ewing's on the Steam Engine in the Encyclopædia Brittanica, Sir William Thomson's article on elasticity in the same encyclopædia, Thomson and Tait's Natural Philosophy, and Minchen's Statics. The moment of resistance of a square bar to torsion is given by Saint Venant as $0{\cdot}281\, fh^3$ where f=maximun intensity of stress and h=side of square. Saint Venant gives the correct formula afterward as $0{\cdot}208\, fh^3$. "It seems strange that the talented author of the expressive distinctions, strain and stress, should himself have taken the formula for the strain instead of that for the stress." At the time he wrote however strain and stress were supposed to be proportional to each other.—*Nature*, p. 126, June 7, 1888.

J. T.

4. *Latent heat of evaporation of Water.*—Regnault's experiments were made at temperatures above 0° and he obtained a formula which led to the value 607 units of heat, the latent heat of evaporation at 0°. Dr. Dieterici, by the use of an ice calorimeter has made a direct determination of this constant, and has obtained the value 596·4 thermal units at 0°.—*Nature*, p. 143, June 7, 1888.

J. T.

5. *Electrolysis by alternating currents of Electricity.*—M.M. Maneuvrier and J. Chappuis show that the size of the electrodes exercises a great influence in the electrolysis by alternating currents. With currents of 250 to 300 volts and 4 to 5 Ampères, no trace of electrolysis can be discovered with electrodes of $0{\cdot}1^{cm}$ in diameter and 4^{cm} to 5^{cm} in length. If one however sub-

stitutes in the same voltameter some very fine electrodes there is an abundant disengagement of gases. The authors give various examples to show that electrolysis by alternating currents is different from that by continuous currents. By a suitable choice of electrolyte, an alternating current can be measured by a voltameter.—*Comptes Rendus*, p. 1719, June 18, 1888. J. T.

6. *Electro-chemical Radiophone.*—CHAPERON and MERCADIER employ a galvanic cell composed of one plate of silver coated by electrolysis of sulphide of sodium with a very thin layer of sulphide of silver, and another plate of silver. Both plates are placed in a liquid conductor, water acidulated with sulphuric acid, for instance. The cell possesses a very feeble electromotive force. It polarizes very rapidly and gives rise to variable instantaneous currents under the action of very feeble light. By means of a radiophonic wheel an intermittent beam of light corresponding to a tone of 1000 vibrations was allowed to fall on the cell, and the note was heard in a telephone enclosed in the circuit. This note was due to an electrochemical effect, the duration of which was less than $\frac{1}{2000}$ of a second.—*Comptes Rendus*, No. 23, p. 1595. June 4, 1888. J. T.

II. GEOLOGY AND MINERALOGY.

1. *On the Black Hills of Dakota;* by Prof. W. O. CROSBY.—A paper in the Proceedings of the Boston Society of Natural History for March 7, 1888 (p. 488), describes the rocks of the Black Hills, and shows that the great granite masses, which occur in the western portion of the Archæan area, consist really of vein granite. This is shown by their position and coarseness of texture. He makes also the important observation that the high conical masses of rhyolyte and trachyte of the northern end of the Black Hills, described by Prof. Henry Newton, are true laccoliths. Speaking of the Paleozoic rocks he remarks on the perfect conformability of the Carboniferous beds on the Cambrian with which they are in contact, the intervening Silurian and Devonian being absent. The unconformability of the Cambrian on the Archæan is to be seen at all contacts.

2. *Annual Report of the Geological Survey of Pennsylvania for* 1886.—Parts II and III of this report have been issued. Part II treats of the Oil and Gas Region, and contains the detailed report of Mr. J. F. Carll, covering over 200 pages and also a paper on the Chemical Composition of Natural Gas by Prof. F. C. Phillips. The gas of Fredonia, N. Y., was found to contain 90·05 p. c. of hydrocarbons of the paraffin series (in which methane predominates), 9·54 nitrogen and 0·41 carbon dioxide. This is about the average of the results obtained. But the Murrysville gas, a very productive well, afforded 97·70 of paraffins and only 2·02 nitrogen, and 0·28 CO_2; while the Houston gas, from a well two miles south of Canonsburg, Pa., afforded 84·26 paraffins, 15·30 of nitrogen and 0·44 CO_2.

Part III consists of the Report of Mr. Frank A. Hill on the Anthracite Coal Regions.

3. *Geological and Scientific Bulletin.* Published by the Texas State Geological and Scientific Association, at Houston, Texas. (Fifty cents per annum).—No. 2 of this new Geological publication bearing the date of June 2, 1888, is a four-paged folio. It contains geological communications on Texas and Arkansas by Mr. R. T. Hill and others, besides papers bearing on the mining industry of Texas. The region is to be surveyed under State auspices, and the paper will announce results as they may be developed and also report on observations in other departments of science. The survey has been put under the direction of the Commissioner of Insurance, Statistics and History, and by him the geologists will be appointed. An appropriation of $15,000 has been already made.

4. *The Genealogical Tree.*—Prof. J. W. JUDD, in his excellent Anniversary Address of February last before the Geological Society of London, has the following wise remark: "One of the most mischievous weeds that have accompanied the evolutionist in his incursions into various parts of the biological field is the preposterous 'genealogical tree.' We can scarcely turn over the leaves of a modern systematic work without finding it flourishing in full luxuriance. No sooner has the student of a particular group arranged his families, genera, and species, than he thinks it incumbent upon him to show their genetic relations. Very admirably has Professor Alexander Agassiz pointed out the utter fatuity of such a proceeding. As Lyell used to say, in speaking of such proceedings, the imagination of the systematist, untramelled by an acquaintance with the past history of the group, 'revels with all the freedom characteristic of motion *in vacuo*.' If for no other reason, zoologists and botanists ought to study fossil forms in order that, by encountering a few hard facts in the shape of fossils, they may be saved from these unprofitable flights of the imagination."

5. *Estudo sobre os Bilobites e outros Fosseis das Quartzites da Base do systema Silurico de Portugal.* Supplement: by J. F. N. DELGADO, Director of the Geological Survey of Portugal. 76 pp. 4to, with 9 plates.—This supplementary report by Prof. Delgado consists largely of a reply to the criticisms of M. Nathorst in his report on the same subject of 1887, but contains also descriptions and figures of new kinds. The plates are phototypes, and represent some remarkably fine and large forms; they appear to sustain the author's conclusions as to their vegetable origin. The last two plates represent large species having the markings of *Arthrophycus Harlani* of Hall, making this genus (if not the species) of much earlier date than known from the American rocks. Prof. Delgado names them *A. Harlani*, although much larger than the American species.

6. *British Petrography with special reference to the Igneous Rocks;* by J. J. HARRIS TEALL, M.A., F.G.S. 451 pp. 4to, with

47 plates. London, 1888 (Dulau & Co., Soho Square).—The numerous active workers in English petrography, among whom the author of the present work is included, have shown that a remarkably wide range of igneous rocks is included in the confines of Great Britain. To give a complete and systematic account of these, within the compass of a single volume, is a serious task, but one which the author has accomplished in an admirable manner. A minute personal knowledge of the rocks themselves, and wide reading of the literature of the subject abroad, has equipped him well for the work. The opening chapters are devoted to a general statement as to the forms taken by the constituents of igneous rocks, and to a discussion of the chemical and physical characters of the rocks. The author wisely regards rocks, not so much from a narrow mineralogical point of view, with reference only to the minerals of which they are composed, but more broadly with regard to their general chemical composition. He also shows independence in cutting loose from the age criterion as a fundamental basis for classification and nomenclature. He insists strongly upon the distinction between the basic and acidic members of the rock series. In this connection he emphasizes the effect of crystallization on an igneous magma to increase the relative amount of silica and alkalies, and further in the alkalies to increase the potash relatively to the soda. He quotes here a series of analyses, from widely different sources, bringing out these facts and refers to the work of Rosenbusch as showing that they are confirmed by microscopic examination.

The classification adopted divides the rocks into a series of groups passing from the basic to the acidic, according to the chief mineral constituents present; further, under each group the distinction in structure between "*granitic*" and "*trachytic* texture" forms a basis of further subdivision.

The first group includes the so-called ultra-basic rocks, that is, those made up of olivine alone, or with some form of pyroxene or amphibole without feldspar. The basic group follows, the rocks characterized by plagioclase with olivine, pyroxene, amphibole and biotite. This passes through the rocks of intermediate composition to the third group characterized by the presence of orthoclase with the various other minerals named. The rocks containing nephelite and leucite follow and then certain forms not easily included in the preceding divisions. The glassy and fragmental rocks close the series. Under each group a general summary is given of the constituent minerals and of the rocks as they appear elsewhere; in this portion of the work the author shows a full knowledge of the extended literature of the subject. Then follows a somewhat minute account of the British rocks falling into the place, based upon the exhaustive studies of Judd, Allport, Rutley, Worth, Teall and others. Of the various rock types falling into the groups mentioned, the majority are fully represented and have been thoroughly studied; certain kinds, however, for example those of the nephelite, leucite series, the

recent andesites, are absent; only a single case of a rock with nephelite being known. A series of forty-seven plates accompanies the text description. These are of excellent execution, well drawn and very delicately colored, and with key plate accompanying each, show clearly the many points to be illustrated.

7. *Brief notices of some recently described minerals.*—LANSFORDITE.—A white translucent mineral, somewhat resembling paraffin, but having a crystalline structure and vitreous luster; a prismatic angle of 76° was measured. Hardness 2·5, specific gravity 1·54–1·692. An analysis by Keeley gave

CO_2 18·90, MgO 23·18, H_2O 57·79 = 99·87.

Of the water, the loss over H_2SO_4, after 20 hours, was 4·83 p. c., after 48 hours 11·70, after a week 26·33, at 110° C. 12·31, at 185° C. 9·76, at a red heat 9·39. The formula deduced is $3MgCO_3$, $Mg(OH)_2 + 21H_2O$. The mineral was found as a stalactitic growth at the anthracite mine of Lansford, near Tamaqua, Schuylkill Co., Penn.—F. A. GENTH in *Zeitschr. Kryst.*, xiii, 255.

HORSFORDITE.—A massive mineral resembling native silver in color, with high luster, but soon tarnishing. Hardness 4–5, G. = 8·812. An analysis gave

($\frac{3}{4}$) Antimony 26·86. Copper 73·37 = 100·23

which corresponds to a compound between Cu_5Sb and Cu_6Sb, very near to $Cu_{11}Sb_2$. It is thus related to some forms of dyscrasite, also to algodonite. It occurs as an extensive deposit near Mytilene in Asia Minor.—A. LAIST and T. H. NORTON in *Amer. Chem. Journ.*, x, 60.

HOHMANNITE, AMARANTITE.—Described as two independent hydrous iron sulphates, occurring with copiapite from Chili. Hohmannite is a chesnut-brown massive mineral with a fibrous structure. Hardness 3, specific gravity 2·24. An analysis gave

SO_3 30·88, Fe_2O_3 40·05, H_2O 29·63 = 100·56

for which the formula $2Fe_2O_3$, $3SO_3 + 13H_2O$ is calculated. Amarantite occurs in microscopic crystals of an orange color. The analysis gave

SO_3 37·26, Fe_2O_3 35·58, H_2O 27·62 = 100·46

leading to the formula Fe_2O_3, $2SO_3 + 7H_2O$. A later trial of hohmannite gave a result nearly identical with this, making it probable that the two minerals have really the same composition and are identical, though occurring in a different form. A. FRENZEL in *Min. Petr. Mitth.*, ix, 397, 423.

QUENSTEDTITE, BÜCKINGITE.—In a preliminary notice of some iron sulphates from Chili, the name *Quenstedtite* is given to a salt occurring in reddish-violet tabular crystals resembling gypsum. They belong to the monoclinic system and have the composition

$2FeO_2H + 8Fe_2(SO_4)_3 + 10aq.$

Bäckingite occurs in dark brown thick tabular crystals belonging to the triclinic system. The formula given is

$2Fe_2(SO_4)_3 + 2H_2SO_4 + 7FeSO_4 + 60aq.$

—G. LINCK in *Jahrb. Min.*, vol. i, 213, 1888.

8. *Mineralogical Notes.* (1) *Vesuvianite from Newbury, Mass.;* by W. O. CROSBY and JAMES T. GREELEY.—An investigation with analysis of a massive mineral occurring with serpentine in the lime quarries of Newbury, Mass., has proved that it is vesuvianite, and not massive garnet, as has been supposed (Dana's Mineralogy).

(2) *Gahnite from Rowe, Mass.;* by W. O. CROSBY and CHARLES L. BROWN.—A partial analysis is given of the zinc spinel occurring with pyrite at Rowe, Mass. The authors announce the occurrence as a new discovery, evidently not having seen the paper on the subject by A. G. Dana, published three years since (this Journal, xxix, 455).—*Technology Quarterly*, i, 407, 408, May, 1888.

9. *Brazilian Meteorites.*—Seven Brazilian meteorites are represented in the collection of the National Museum of Rio de Janeiro of which only three (Bendego, Santa Catherina and Macau) have been previously described. The new ones are: *Itapicuru-mirim* (Prov. de Maranhão) March, 1879, chondrite, weight 2·024 grams, spec. grav. 3·638. *Santa Barbara* (Prov. de Rio Grande do Sul) Sept. 26, 1873, chondrite, weight of two authentic specimens, representing apparently about a quarter part of the single stone collected, 93·211 grams, spec. grav. 3·478. *Minas Geraes?* Date and place of fall unknown, but supposed to be from the province of Minas Geraes, chondrite, weight 1·224 grams, spec. grav. 3·48–3·51. *Angra dos Reis* (Prov. de Rio de Janeiro) Jan. 15–31, 1869, Angrite (Ludwig and Tschermak, Min. Mitth., 1887), weight of a piece representing about a quarter part of the original mass, 446·5 grams, spec. grav. 3·43–3·47; composition augite 93·28, olivine 5·45, magnetic pyrites 1·27.

A fragment of a chondrite labeled "Rio de Janeiro" is presumed to belong to the Santa Christina meteorite. A stone from Ponta Grossa, province of Paraná, sent to the Emperor in 1867 and described as having a syenitic aspect with a wrinkled reddish crust (Eukrite or Howardite?) has disappeared. A fragment of iron in Claussen's collection presumed to be the one referred to by him (Bull. de l'Acad. Bruxelles, 1841) under the name of the Curvelle meteorite, is artificial, as is also a reputed meteorite at Areado, in the province of Minas Geraes. Another pseudo-meteorite is an artificial mass of metal said to have fallen June 14, 1861, near Curitiba, prov. of Paraná. It has not yet been definitely ascertained if a meteorite fell on that day or not. Meteorites are also reported from Morro do Chapeo and Monte Alto in the province of Bahia in regard to which no definite information has been obtained.—(*O. A. Derby*, in *Revista do Observatorio of Rio de Janeiro.*

10. *Note on the Locality of the Santa Catharina Meteorite.*—The masses of iron known by this name were found scattered over a triangular area of about 10,200 square meters at a distance of 4,200 meters from the city of São Francisco do Sul on the island of the same name. This portion of the island is composed of gneiss and granite cut by dykes of diabase. The soil about

the iron is clearly of granitic origin and large blocks of tourmaliniferous granite occur close by one of the points where iron was found. No evidence of the existence of basic eruptive rocks such as are required by the hypothesis that the iron is similar in origin to that of Ovifak could be found in the vicinity, though from the lack of rock exposures, the depth of the soil cap and the thick covering of second growth timber, it cannot be positively affirmed that none such exist. On the whole the evidence, though not conclusive, is in favor of the meteoric rather than the terrestrial origin of the iron. About 25000 kilograms are reported to have been shipped to England to be smelted for nickel. The only fragments to be found at present are almost entirely reduced to the state of oxide.—(*Luiz F. Gonzaga de Compos* in *Revisto de Observatorio of Rio de Janeiro*).

11. *The Bendego Meteorite.*—This famous mass of iron was landed in Rio de Janeiro June 15th, and is now in the National Museum of that city. The transportation over 115 kilometers of mountainous country to the nearest railroad station was directed by Chevelier José Carlos de Carvalho in the name of the *Sociedade de Geographia de Rio de Janeiro*, the necessary funds, amounting to about $10,000, being generously furnished by Baron Guahy. The weight verified on the scales of the Bahia R. R. is 5,361 kilograms. The comparative thickness of the crust of oxide formed since the first attempt to remove it in 1785, and that found in the original resting place, afford a basis for a rough guess at its age which may safely be put down as over six centuries.

III. Botany.

Notices of recent contributions to Vegetable Physiology.—(For other recent papers, bearing more particularly on the vegetable cell, see this Journal, March, 1888).

(1) *A. H. de Vries's studies of Glycerin in its relations to certain tissues.*—In Botan. Zeitung for April 1888, this investigator publishes a few notes in regard to the absorption of glycerin by vegetable cells, which have a high degree of interest for all who are in the way of examining the behavior of cells when placed in this medium. It was shown by Klebs last year that this substance is very easily taken up by the cells of living Zygnema, diffusing with facility into their interior. Moreover it was pointed out by Arthur Meyer in 1886, that when the green parts of plants are placed in glycerin it is possible for them to produce starch therefrom, a fact of great importance in view of the fact that glucose has been synthetically produced from glycerin-aldehyd (Fischer and Tafel, 1887). But, as is well known, glycerin is a powerful plasmolytic, acting in a 10 per cent solution to cause distinct contraction, and even in a much more dilute solution acting more or less plainly. After an hour or so, the contraction diminishes gradually and finally passes away, while in a solution of 5 per cent, growth takes place, and the Zygnema remains fresh and healthy even for four months in the dark.

It appeared therefore of importance to ascertain accurately the quantitative relations of glycerin to tissues, and this has been attempted by DEVRIES in the paper referred to. His method is essentially the same as that employed by him in his previous series of plasmolytic experiments, and the material is the same, namely,—the red epidermis of the petiole of *Begonia manicata.* From the epidermis of the upper side of the petiole about twelve good microscopic slices are taken, and subjected at once to the action of the plasmolytics, such as potassium nitrate or sugar, of different degrees of strength. After two hours it is possible to detect in the sections placed in the stronger solutions the beginning of the plasmolysis, and afterwards one may trace its further progress in the weaker ones. From these observations deVries determines the isotonic coefficient for glycerin to be 1·78.

When this figure is compared with the coefficients of some other substances, and also with the figures obtained by Raoult for the lowering of the freezing-point, the curious relations are confirmed.

Glycerin,	1·78	17·1
Cane-sugar,	1·88	18·5
Inverted sugar,	1·88	19·3
Malic acid,	1·98	18·7
Citric acid,	2·02	19·3
Tartaric acid,	2·02	19·5

deVries has also measured the permeability of the protoplasts by glycerin, but he gives only a few results as an example of the working of his general method.

(2) *Assimilation by colored and variegated leaves.*—ENGELMANN to whom we are indebted for a method of quantitatively estimating the effects of different rays of the solar spectrum in assimilation, has extended his observations to variegated leaves, and to those which have a uniform color other than green. (Bot. Zeit., xlv. no. 25.) Passing over his studies as to the structure of the parenchyma of the leaves, and merely stating that he distinguishes between colors which depend (1) on the cell-wall, (2) on the cell-sap, and (3) on the plastids themselves, it may be said that he presents results confirming to a certain extent his former views as to the relation of the absorption-bands and assimilative activity. Without dwelling upon the possible errors of his method, it is enough to call attention to a marked advantage which it has over any other in the determination of the amount of activity in a single cell or group of cells. The method, it will be remembered, consists essentially in the application of a small direct-vision spectroscope under the stage, throwing the light through the diaphragm upon the under side of an object placed in the field. By the activity of bacteria in the water surrounding the object (assuming that this activity is due to the elimination of oxygen during the process of assimilation), Engelmann endeavors to ascertain the relative amount of assimilation in different parts of the spectrum. When, as in the case of large leaves or fragments of

green twigs employed in the ordinary method by exposing the whole to the different rays, it is seen that the greatest assimilation takes place in the orange rays, or those of medium refrangibility, it is impossible to detect any relation between the absorption bands and the amount of oxygen given off. Hence, with all the objections which may be urged against it, Engelmann's method places in our hands the means for estimating the effects in a strictly localized part of the field. When, therefore, the method is applied to the different parts of a variegated or colored leaf, we may reasonably expect to determine the difference in the efficiency of the rays belonging to the different parts of the spectrum. It is fair to say that the present paper appears to strengthen the position originally assumed by Engelmann in the questions to which his methods and conclusions have given rise. He has given also some useful hints as to the employment of his method which obviate a few of the objections formerly raised against it. G. L. G.

(3) *Hough's American Woods. Part I;* by ROMEYN B. HOUGH, Lowville, N. Y.—This work consists of transverse, radial, and tangential sections of twenty-five species of our North American woods, having a thickness of perhaps one-hundredth of an inch or in some cases a good deal less, and measuring two inches by a little more than four. A few of the specimens are somewhat thicker than this, but they are all sufficiently thin to reveal the structure of the wood. The sets are furnished at the low price of five dollars for the twenty-five species, and some of the species are represented by more than one series of sections. These sets remind one of the beautiful preparations made for schools by Mr. Spurr, under the direction of Mr. Henry Brooks of Boston, but they do not possess as those did, the advantage of protection by thin plates of mica, which rendered the latter of great service in botanical classes. Mr. Hough's specimens are equally beautiful, but in their unprotected condition one would hardly like to trust them in the hands of ordinary students. It is to be sincerely hoped that Mr. Hough will be encouraged to continue his interesting and useful work. The sections are accompanied by a short account of the elements of botany, together with the more important facts relative to woods, and the whole treatise is followed by a specific statement regarding all the plants used in the illustrations. G. L. G.

Journal of the Trenton Natural History Society.—The number of this Journal for January, 1888 (No. 3), contains a paper by Dr. A. C. Stokes on Fresh-water Infusoria, and one by W. A. Stowell on the Flora of Bergen Co., N. J.

Bulletin of the Natural History Society of New Brunswick, No. VII, published at St. John, New Brunswick, contains a review of the Echinodermata of New Brunswick, by Mr. W. F. Ganong.

Obituary.

Amos H. Worthen, the distinguished geologist of Illinois, died on the sixth of May last, in his 75th year, leaving behind him, in the volumes of the Illinois Geological Survey, a lasting monument to his memory.* Mr. Worthen was born October 31, 1813, at Bradford, Orange County, Vermont, being next to the youngest of the thirteen children of Thomas Worthen and Susannah Adams. His mother was a descendant of the Adamses of colonial times. In August, 1834, he went with his young wife —having married in the January preceding Miss Sarah B. Kimball, of Warren, New Hampshire—to Harrison County, Kentucky, and there for a year or two taught school. In June, 1836, he moved to Warsaw, Illinois, which was his home until his death, with the chief exception of two years between 1842 and 1844 spent in Boston on account of Mormon troubles in Illinois. While engaged in commercial business, he became interested in the science of geology, and made large collections of fossils and also of the remarkable geodes of the Keokuk limestone in the region. On the institution of the Geological Survey of Illinois in 1851, under Prof. J. G. Norwood, he was selected as his assistant, and continued his labors in this position until 1855; but little was published as results of the survey owing to the inadequate appropriations by the State. From 1855 to 1857 he was assistant under Professors James Hall and J. D. Whitney in the Geological Survey of Iowa; and the large volume published in 1858 owes very much of its value and interest, says the Report, "to the labors of Mr. Worthen in the field, and for the loan of his magnificent collection of Carboniferous Crinoids, as well as of other fossils." "But for this liberality, the work would have been far less fully illustrated. Such collections can only be accumulated by the devoted attention of many years; and in expressing my own indebtedness to Mr. Worthen, I may express the obligations under which geology rests for this contribution, and which will be gladly acknowledged by every student and votary of science." The many beautiful plates of the large volume are from drawings by Mr. F. B. Meek, who was afterward associated with Mr. Worthen in the paleontology of his own reports. This Iowa Report with its many plates of wonderful Crinoids should bring to mind the name of Worthen.

In March of 1858, Mr. Worthen took charge, by State appointment, of the Geological Survey of Illinois. The survey was carried on until 1872. After this date, he continued the study and care of the collections, with the title of Curator of the Illinois State Museum, completing and issuing from time to time the large and copiously illustrated volumes of his Report. Already in 1860, advance results of his work, in connection with Mr. Meek, appeared in the Proceedings of the Academy of Natural Sciences

* For many of the particulars with regard to the life of Mr. Worthen we are indebted to Prof. T. B. Comstock.

of Philadelphia; one in September, describing 29 new species of Crinoids, and another in October, describing 69 new species of mollusks and other fossils; and these were followed by others of similar character.

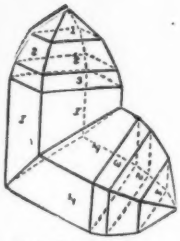
The first and second volumes of his Geological Report made their appearance, in Royal Octavo, in 1866, the first, largely stratigraphical, the second, mainly paleontological. The latter contained descriptions and figures of 118 species of fossil fishes (by Newberry and Worthen), 156 of invertebrates, including Crinoids, etc. (by Meek and Worthen), and 50 of coal plants (by Mr. Lesquereux). These volumes were followed two years later by the third; and others slowly appeared, the seventh with 26 plates devoted to fossil fishes and others to Crinoids, etc., in 1883. Together the series is unsurpassed in importance by any of those of the other States, especially in the departments of Crinoids, Articulates, and Subcarboniferous Fishes.

Mr. Worthen left an eighth volume in the press. Besides these volumes of reports Mr. Worthen issued a large colored Geological Map of Illinois; published three volumes on the Economical Geology of the State compiled from his Geological Reports, and was the means of gathering for the State Museum one of the largest collections of fossils in the country.

In the early part of the survey Mr. Worthen encountered and overcame great opposition. His modesty and earnestness, high character and quiet dignity gave him great influence, and the many difficulties disappeared before him. Although nearly seventy-five years old at his death he had not given up work; the preparation of the text and plates illustrating the descriptions of the Silurian invertebrate fossils of Illinois, for the eighth volume, was occupying him, when a sudden attack of pneumonia brought all to an end. The Governor of the State, Governor Oglesby, in a telegram to the family, most fittingly said: "In his death the State loses a useful private citizen, a faithful public officer, and an ardent and laborious friend of Science."

Of the seven children of Professor Worthen, the only daughter died in infancy. His six sons are still living. The name of one, Charles K. Worthen, appears as the draftsman on many of the plates in the later volumes of his father's reports. Professor Worthen's wife died a year before him, on the 13th of January, 1887.

J. D. D.



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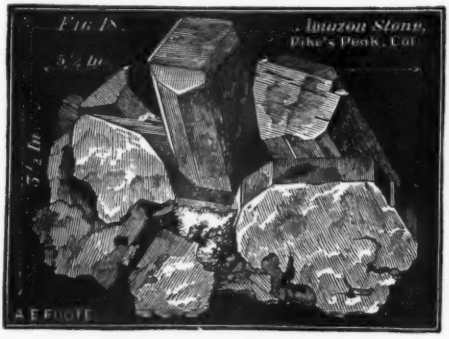

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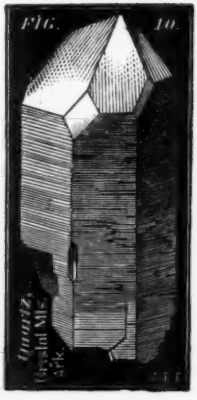

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DANA'S WORKS.

IVISON, BLAKEMAN, TAYLOR & Co., New York.—**Manual of Geology,** by J. D DANA. **Third Edition,** 1880. 912 pp. 8vo. $5.00.—**Text-book of Geology** by the same. **4th ed.** 1883. 412 pp. 12mo. $2.00.—**The Geological Story Briefly Told,** by the same. 264 pp. 12mo. 1875.

J. WILEY & SONS, New York.—**Treatise on Mineralogy,** by J. D. DANA. 5th edit. xlviii and 828 pp. 8vo., 1868. $10.00. The 5th "subedition" was issued by Wiley & Son in April, 1874. (Each "subedition" (or issue from the stereotype plates), contains corrections of all errors discovered in the work up to the date of its publication). Also, Appendix I, by G. J. Brush. 1872. Appendix II, by E. S. Dana, 1875.—**Manual of Mineralogy & Lithology,** by J. D. DANA. 3d edition. 474 pp. 12mo., 1878.—**Text-book of Mineralogy,** by E. S. DANA. Revised edition. 512 pp. 8vo., 1883.—**Text-book of Elementary Mechanics,** by E. S. DANA. 300 pp. with numerous cuts, 12mo., 1881.—**Manual of Determinative Mineralogy,** with an Introduction on Blow-pipe Analysis, by GEORGE J. BRUSH. 8vo., 2d ed. 1877. Third Appendix to Dana's Mineralogy, by E. S. DANA. 136 pp. 8vo. 1882.

DODD & MEAD, New York.—**Corals and Coral Islands,** by J. D. DANA. 398 pp 8vo, with 100 Illustrations and several maps. 2d ed., 1874.

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ERRATUM.

Page 73. line 18 from bottom, for *under charge of*, read *under a contract with.*